A MATHEMATICAL ANALYSIS OF PLANNING, GOAL FORMULATION, AND RESOURCE ALLOCATION IN AN ORGANIZATIONAL SYSTEM

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SUMMARY

The primary focus of this research study is on the development and analysis of analytical models for goal formulation and resource allocation in an organizational system comprised of three major classes of participants: top level managers, middle level administrators, and clients of the organization.

A goal programming formulation of an overall problem facing the organizational decision system is given and the problem is decomposed using a goal partitioning approach. The decomposed problem consists of a master problem, which is viewed as being solved by top level management, and two types of subproblems, one associated with the middle level management and the other associated with the organizational client. The solution procedure reflects the interaction and information flow between middle level management and top management and between client and top management. Several attributes of the model are consistent with observed behavior in organizations.

Three models, which represent three distinct decision situations which may occur when the organization has one output and multiple clients, are presented. The first model describes a situation in which the top management desires to minimize the dissatisfaction of the middle level management and the sum of weighted client dissatisfactions with the product or service of the organization. The second model describes a situation in which either it is necessary to "target" or select one of many clients or it is necessary to keep the dissatisfaction of all clients within threshold levels given a "target" client. The third model describes a situation in which the top management desires to minimize the dissatisfaction of the middle level management and the maximum client dissatisfaction with the organization's output.

The above-mentioned models are normative and are developed to aid in designing better interaction and coordination processes. In addition, several descriptive models, which reflect observed behavioral interactions, are developed. One description considers the client's influence upon the top management, termed indirect influence. A second description considers the client's influence directly upon the middle level management, termed direct influence. Two methods of describing a project redesign phase are presented. Several opportunities for additional reserch are noted.

CHAPTER I

INTRODUCTION

Background

The recent development of large-scale mathematical programming decomposition models and algorithms [65,6,35,36,9,107,15,57,60,70,69, 105,46,67,106] which appear to resemble interactions and information flows in hierarchically decentralized organizations, has led operations researchers toward the development of models which portray the organizational information flows associated with the resource allocation process. However, some of the recent models [91,30,45] consider only implicitly the effect of the clients or consumers of the organization in influencing resource allocation decisions made within the organization. The models concentrate upon the interaction between superiors and subordinates, which interaction occurs for the purpose of establishing goals and objectives for subordinate management units and determining future resource allocation levels.

Recent organizational, marketing, and advertising research studies [71,51,58,101,32,41,37,39,50,7,1,3,13,27,53,64,78] either provide evidence or propose hypotheses which emphasize the influence of the environment surrounding the organization. More specifically, the emphasis is on the power of a person or group outside the organization to produce effects without the exertion of any physical force or authority. In many situations this person or group is referred to as the client or consumer. In the simplest case, a client may affect the decision-making process in an organization by his decision whether or not to buy or utilize a product or service produced or provided by the organization. In a more complex situation, the client may provide information relating to his dissatisfaction or preference which might be used by the organizational decision makers to produce a product or provide a service which is more satisfactory or more useful to the client.

Aim

The purpose of this research is to develop analytical models of a resource allocation-decision making process within a hierarchical decentralized organization which include an explicit incorporation of client influence upon organizational output and product redesign. The decision-making process is analyzed via mathematical programming models. It is hoped that this research will aid in further bridging the gap between behavioral sciences and operations research.

Scope of the Research

This study is specifically directed toward the development of analytical models which can be analyzed to provide insight into the resource allocation process. The process is viewed as iterative in nature, and since it takes place over time, a model of the process, which reflects changes over time, is used. For convenience, linear models are assumed. In addition, it is assumed that behaviors of individuals within the organization and the clients of the organization are goal directed. A goal programming model is seen to have desirable properties in describing goal directed behavior and is selected as a component in a proposed organizational system model. An organizational system model is proposed which incorporates client interaction in the decision-making process as well as superordinate-subordinate interaction.

Chapter I is an introduction and includes the background, aim and scope of this research.

Chapter II presents a formal definition of an organization, a discussion of goal-oriented and systems-oriented approaches of viewing organizations, a consideration of some of the difficulties associated with using quantitative performance measurements in organizations, and a basis for proposing an organizational system model.

Chapter III reviews the models of Goodwin [50], Baker [7], Ruefli [91], Collomb [30] and Freeland [45]. A review of the mathematical programming literature dealing with decomposition as applied to the organizational decision-making process is presented.

In Chapter IV, a mathematical model of an organizational system model based on Freeland's goal-partitioning model is presented. Two approaches to client intervention are modeled: (1) the first approach allows an administrator to determine an output for the client which may not satisfy client-related objectives, and (2) the second approach allows no freedom to an administrator with regard to satisfying client-related objectives. The partitioning model requires interaction with the client at each iteration. Thus the client is treated similar to an additional subordinate unit. A decision model for product redesign is also presented. The models describe a situation in which the organization produces one product or service and there is only one client or client group.

Chapter V presents three decision rules when there is one product or service and there are several groups of clients. It is assumed that individuals within a group have a homogeneous set of needs and the needs are seen as heterogeneous between groups. The three rules considered are

1. Minimizing the sum of internal tension and weighted client dissatisfaction.
2. Targeting a client group which minimizes the sum of internal tension and client dissatisfaction.
3. Minimizing the sum of internal tension and maximum client dissatisfaction.

Chapter VI presents several descriptive models of the interaction among the central unit, management units and client. The models, although similar in nature to those considered in Chapter IV, consider client evaluation of the actual output of the organization which occurs only after the central unit--management unit interaction results in a satisfactory allocation of resources and requirements within the organization. Two processes of client influence--indirect, in which the client attempts to influence the central unit, and direct, in which the client seeks to influence the management units--are described. In addition, two models of the project redesign process are described.

Chapter VII presents the conclusions and recommendations for future research.

CHAPTER II

SINGLE GOAL AND SYSTEM APPROACHES TO STUDYING ORGANIZATIONS

Students of organization theory have proposed many definitions of organizations, have used varying assumptions and have changed the observation viewpoint in their studies. The purposes of this chapter are to define a formal organization, to define a set of postulates which will be used throughout this dissertation, to discuss both a goal-oriented and a systems-oriented approach to viewing organizations, and to present the arguments for selecting a systems-oriented approach. In addition, the difficulties encountered in attempting to use quantitative performance measurements are considered, the purpose of using a mathematical analysis is discussed, and finally an organizational system approach to studying organizations is defined.

Definition of an Organization

The organization is usually thought of as the company, the corporation, the university, the welfare agency, etc. Chester Barnard's [10] definition of an organization is an acceptable one throughout this thesis. Barnard [10] defines a formal organization as a "system of consciously coordinated personal activities or forces of two or more persons" [10, p.73]. The formal organization is thus a cooperative system which is "a complex of physical, biological, personal and social components which are in a systematic relationship by reason of the co-operation of two or more persons for at least one definitive end" [10, p. 63]. The definitive end that Barnard relates to may be considered as the purpose or goal of the organization. However, it is well to note the difference between a purpose and a goal. Webster (1963) defines *purpose* as "the object for which something exists or is done" and *goal* as "an object or end that one strives to attain." Purpose may be viewed as an external or impersonal object, hence, Barnard postulates that a common purpose of an organization is necessarily an external, impersonal, objective thing. On the other hand, a goal may be perceived as an internal or personal object. Thus, the use of the term *purpose* in reference to an organization appears to connote a depersonalization of an organization. The organization is treated as an object or thing rather than a collection of individuals in cooperation. But it is the individual working with other individuals, not the building, the machines or the product, which constitutes an organization. Therefore, the definitive end, toward which the individuals in a coordinated effort strive to attain, should be described in terms of a goal or goals.

At this point, however, it is not at all clear as to whether an individual or organization actually has a goal or whether it only appears to the students of organizations that an individual or organization has a goal. Economists refer to the profit motive of an organization as its goal and sociologists refer to organizational survival as an organization's ultimate goal. But does this mean that an organization, which does not make a profit, does not have a profit goal, or an organization, which does not survive, does not have survival as a goal? Or, have these respective organizations simply failed in reaching their goals? Perhaps a more basic question would be, do organizations actually have goals? To alleviate the difficulty involved in attempting to answer these questions, the following set of postulates is given:

1. It is assumed that organizations do have one or more goals which can be specified.
2. Individuals in the organization may have goals which are not shared by all individuals in the organization.

A Single Goal Approach to Organizations

The single goal approach to organizations suggests that there exists only one major unifying goal in the organization. And in evaluating the performance of an organization, multiple measures are often regarded as a poor substitute for the one best index of performance [52, p.1178].

A review of the literature related to business organizations by Dill [38] reveals that

> . . . the simplest and strongest hypothesis about the goals of business organizations is that they are concerned only with profit and in all that they do, they strive to maximize profit. . . . Ideologically, the single-minded emphasis on profits is regarded by many as the cornerstone to the success and survival of a capitalistic society [38, p.1073].

However, Dill further indicates that proof of this emphasis is scarce.

The mathematical programming literature gives abundant examples in which maximization of profit is the single objective function. Collomb [30] writes,

> The classical profit maximization model starts from the idea that individuals or corporations engage in business, for most of them,

> with the avowed purpose of making a profit, and that profit-seeking behavior seems to have been the essential driver of business entities in the western economies. This descriptive view is backed up by some normative considerations drawn from economic theory [30, p.8].

Traditionally, much of the work that has been conducted in studies attempting to measure the effectiveness of organizations has utilized the goal-oriented approach as is evidenced in an inventory of organizational effectiveness by Price [85]. Price presents an analysis of 50 studies related to organizational effectiveness. Price defines effectiveness, the dependent variable in his study, as the degree of goal achievement. Also, he focuses upon operative rather than what may be considered official goals. Operative goals "designate the ends sought through the actual operating policies of the organization" as opposed to the official goals which are the "general purposes of the organization as put forth in the charter, annual reports, public statements by key executives and other pronouncements" [85, p.855]. Price indicates that there exists a problem of standardizing a measure of effectiveness since relatively few studies of organizations have dealt explicitly with effectiveness and when they have, "diverse measures of effectiveness have been used" [85, p.5].

In Price's inventory, the most generally used measures of effectiveness are productivity, conformity, morale, adaptiveness (i.e., the degree of flexibility), and institutionalization (i.e. the degree to which the decisions of the social system are supported by its environment). But in all cases, if productivity and some other measure were used, productivity was assumed to be most related to effectiveness and thus took precedence in the analysis.

In the single goal approach to organizations, the organization is viewed as a group of individuals bonded by a common objective, usually profit for a business concern, and interaction with the environment would be necessary only if that interaction aided in attainment of the common goal.

A Systems Approach to Organizations

Parsons [83] is one of the first individuals to place a high emphasis on using a systems approach in viewing an organization and the effectiveness of an organization. A system may be defined as a set of components and of the relationships which hold among those components. Parsons defines an organization as a "social system which contributes to a major function of a more comprehensive system, usually society" [83, p.63]. The basis for a systems approach, then, is not specifically a goal-attainment approach, which tends to place the organization in a semi-vacuum where the only interaction with an outside environment is for the achievement of a specific purpose. Instead, as a subsystem, the organization must function as an integral component in which the

> . . . value system of the organization must imply basic acceptance of the more generalized values of the superordinate system . . . [and] the most essential feature of the value system of an organization is the evaluative legitimation of its place or "role" in the superordinate system [83, p.67-8].

In a criticism of Parsons' proposal, Seashore and Yuchtman [93] indicate that he

> . . . failed to adhere to the organizational frame of reference; for Parsons, organizational effectiveness lay in the functional

contribution of the organization to meeting the needs of the larger society. This solution is not tenable, for it merely shifts the same problem to a higher level of social organization [93, p.392].

Georgopoulos and Tannenbaum [49] have viewed the organization at a lower system level. They consider the organization as being a system itself rather than a part of a larger society. In this context, they define the effectiveness of an organization as "the extent to which an organization as a social system, given certain resources and means, fulfills its objectives without incapacitating its means and resources and without placing undue strain upon its membership" [49, p.535-6]. Georgopoulos and Tannenbaum propose three general criteria for measuring the effectiveness of an organization: organizational productivity, organizational flexibility and the absence of strain, tension or conflict. Organizational flexibility, that is, the ability to adapt to its environment, and reduction of strain or tension are going to be major considerations of the analytical models developed in later chapters.

Etzioni [42] also suggests the use of a system model in measuring effectiveness and comments on its advantages over a purely goal-oriented model. The shortcomings of the goal model are suggested by the fact that an organization does not realize its goals effectively and/or an organization may have different goals than it claims to have. In addition, for the "cultural images [goals] to be realized, [they] require an investment of means. Since the means needed are always larger than the means available, social units are always less perfect than their cultural anticipations" [42, p.258-9]. The implication is that entrepreneurs, boards of directors and organizational executives are guilty of making grandiose statements regarding organizational objectives.

Katz and Kahn [62] utilize an open system theory model of an energic input-output system as proposed by von Bertalanffy. In the model, the basic criteria for identifying and determining the function of the system are (1) tracing the patterns of energy exchange as it results in output and (2) ascertaining how the output is translated into energy which reactivates the pattern. The concept of energy is used in the broadest sense as the authors point out:

> The energy reinforcing cycle of activities can derive from some exchange of the product in the external world or from the activity itself. In the former instance, the industrial concern utilizes raw materials and human labor to turn out a product which is marketed, and the monetary return is used to obtain more raw material and labor to perpetuate the cycle of activities. In the latter instance, the voluntary organization can provide expressive satisfaction to its members so that the energy revival comes directly from the organizational activity itself [62, p.20].

Using the energy concept, Katz and Kahn define organizational effectiveness as "the extent to which all forms of energic return to the organization are maximized" [62, p.165]. More specifically, it is the maximization of return to the organization by economic and technical means and by political means, where political means may be both external and internal. For example, an internal political means would be attaining more productivity from an employee for each wage dollar, whereas an external political means might be the attraction of additional subsidies.

The authors explicitly point out that various frames of reference may be used to study and analyze the organization. Although they view effectiveness from the point of view of an organization, one might also view from a lesser frame, e.g. the individual member or the group, or from a loftier frame, e.g. the society of which the organization is a component.

In viewing the organization as an open system, Lawrence and Lorsch [71] examine the connection between the varying technical and economic conditions outside the organization and the patterns of organization and administration that lead to successful economic performance. The authors state:

> Few efforts have been made, until very recently, to understand their [large organizations'] functioning as a whole. . . . The difficulty is that the essential organizational requirements for effective performance of one task under one set of economic and technical conditions may not be the same as those for other tasks with different circumstances [71, p2].

Restricting themselves to large organizations, the authors indicate concern about two important aspects of the functioning of systems. "First, as systems become large, they differentiate into parts, and the functioning of these parts has to be integrated if the entire system is to be viable. . . . Second, an important function of any system is adaptation to what goes on in the world outside" [71, p.7].

Based on experimental studies, Lawrence and Lorsch develop a "contingency theory" of organizations. They state that "the basic assumption underlying such a theory, which the findings of this study strongly support, is that organizational variables are in a complex interrelationship with one another and the environment" [71, p.157]. Six studies, concerned with the various ways in which organizations are designed in terms of structure and important managerial practices, and the contingent relation this bears to their performance of different tasks in different environments, are reviewed. These studies include the works of Burns and Stalker [22], Woodward [110], Fouraker [44], Chandler [24], Udy [104], and Leavitt [72]. The important aspect of Lawrence and Lorsch's study is that they emphasize the environment and its impact upon decisions made within the organization.

For the purposes of this thesis, an organizational system is meant to include the major participants in the decision-making process within the organization, the clients or consumers who utilize or buy the service or product of the organization and other environmental factors, such as legal or technological constraints. Of course, depending upon the type of organization, the number of major participant groups may vary. For example, Baker [7] focuses upon three major groups in a service organization: funders, servicers, and users. Whereas, Goodwin [50], in discussing a welfare system, considers donors, recipients, administrators, deliverers, and the constituency.

In summary, the systems approach to the study of organizations leads the analyst to view the organization as a complete system, recognizing its components, both mechanistic and humanistic, and its relationship to its environment, other organizations and society. The system viewpoint developed when theorists recognized that although specific goals are important, other variables, such as the maintenance function and the organization's relationship to its environment are also important. Industrial organizations are not in business for the sole purpose of making a profit. Therefore, the effectiveness of an organization cannot be based only on a profit measure or some measure of productivity. As Etzioni clearly points out:

> The goal model leads to unrealistic, Utopian expectations, and hence to disappointments, which are well reflected in the literature of this type. The system model, on the other hand, depicts more realistically the difficulties encountered in introducing change into established systems, which function in a given environment. It leaves less room for the frustrations which must follow Utopian hopes [42, p.276].

Decision makers in an organization have a limited number of resources available for the purpose of achieving the multiple, realistic goals of the organizational system. The organizational system's goals, which would include goals of clients, is mentioned, rather than just the organization's goals, since it may be desirable or in fact necessary (for survival) to provide an output which achieves the goals or satisfies the needs of the client or consumer. Thus, the flexibility of an organization to respond to various client or consumer desires may be considered as an important criterion in analyzing organizational behavior.

Since the organization's goals are really goals of one or more individuals, who may be owners or in positions of power, it is not at all unlikely that other individuals in the organization have goals which may differ from established organizational goals. The resulting atmosphere in the organization would be one of non-cooperation, or at best not full cooperation.

But given that administrators, who are not at the top level in an organization, seek to attain goals of the organization, goals of the client and their own goals and they are able to establish some set of priorities or trade-offs among the goals, then each administrator may be regarded as vying for the limited resources which are assumed to be available for goal attainment. Thus the organization is faced with two problems: resource allocation and coordination. Top level administrators, on the other hand, are faced with the problem of coordinating the efforts of managers at lower levels and allocating resources to achieve a desirable output from a client's viewpoint, to achieve the organization's goals, and to minimize the tension or conflict among the managers.

Difficulties of Quantitative Performance Measurements

It appears that in order for administrators to allocate resources in the operation of an organization, some performance measures would be required. In moving from a conceptual realm, where it is recognized that organizations have multiple goals, to an operational mode, where the decisions must be justifiable, difficulties inherent in the measurement and utilization of the information based upon multiple criteria become apparent.

In a criticism of quantitative performance measurements, Ridgeway [86] comments:

> Quantitative performance measurements--whether single, multiple, or composite--are seen to have undesirable consequences for overall organization performance. . . . Even where performance measures are instituted purely for the purposes of information, they are probably interpreted as definitions of important aspects of that job or activity and hence have important implications for motivation of behavior [86, p.247].

For example, Blau [19] reported that a single criterion of performance (number of interviews conducted) was used in a public employment agency. The interviewers thus tended to complete as many interviews as possible without regard to placement of an individual in a job.

If multiple criteria are used, measures may be in conflict with with one another. There might also be some confusion as to which criteria are more important. Without a single composite measure, the individual must make the trade-offs and establish priorities. Hence, improved over-all performance becomes judgmental and the evaluation of performance improvement may vary between administrator and subordinate.

Composite criteria appear to overcome the deficiencies of both a single criterion and multiple criteria. Weightings are given to each criterion and a single over-all measurement is determined by adding the weighted scores. For example, the American Institute of Management [4] in their *Management of Excellent Managements* use a composite of ten criteria. Some problems may occur in using composite criteria, one of which is that effectiveness may be reduced if the means are not supplied or available to meet an increased performance goal. For example, Stedry [100] has presented experimental evidence which showed that performance improves when goal set by an external source is slightly higher than a subject's aspiration level. However, if a goal is set at too high a level, then performance is poor and may even decrease, indicating that the subject, knowing that the performance goal could never be attained, simply gave up. But in general, it appears that a composite measure of effectiveness could be a useful approach in the study of organizations and it would fit within the systems theory framework.

An Organizational System Approach

Once specific organizational objectives are established, these objectives could be broken down into specific goals for managers in various parts of the organization. However, it is also necessary to have information concerning the client's goals. Knowledge of specific attributes that a product or service should have for satisfying a client, would be useful information that a manager could use in determining resource allocations. It is also important for top level administrators to recognize that lower level decision makers have goals of their own which may influence decisions that are made.

If quantitative measures are assumed to be available for making decisions, recent advances in the mathematical programming literature may allow a normative model of the decision-making process and the information flows among individuals in the organizational system.

It would appear to be advantageous for the leaders of our organizations, be they service or business organizations, to take the initiative in developing specific and hopefully measurable, realistic objectives toward which their organizations should strive. Specific statements regarding short-term and long-term plans and objectives, with the recognition that organizational goals can and do change over time could greatly increase the comprehension and acceptance of the organization and its objectives by its managers, employees, consumers or clients, and society. In addition, explicit recognition of the priorities of the goals would aid the decision makers of the organization in determining how resources should be allocated throughout the organization.

It is proposed that an organizational system model be developed which incorporates the needs of the organization's clients or customers, the objectives of the leaders of the organization in the form of organizational goals, the goals of its lower level decision makers, and the legal or technological constraints imposed. In addition, the model should include the interactions which take place among various groups in the organizational system, since these interactions may impact the actual allocation of resources.

In the next chapter, one descriptive and one analytical model, which appear to fit within an organizational system framework, are discussed. Also, three mathematical models, which appear to be useful in developing an organizational system model, are reviewed.

CHAPTER III

MODELS OF INFORMATION FLOW AND RESOURCE ALLOCATION

In the last chapter, the goal model and system model approaches to describing an organization were discussed. It was proposed that an organizational decision system model be developed, in which the goals of individuals within the organization and the goals of the clients of the organization would be important components along with the interactions which take place among the individuals within the system. The basic function of the model is to describe a resource allocation process in an organizational system which is influenced by goals and interactions. In this chapter, the works of Goodwin [50] and Baker [7] are seen to fit the organizational system framework. Baker's model appears to be one of the earliest attempts at an analytical analysis which explicitly includes a client as one of the groups influencing a resource allocation process. Works of Ruefli [91], Collomb [30], and Freeland [45] represent some of the latest work in using large-scale mathematical programming decomposition models to describe resource allocation processes in decentralized organizations. The concepts presented by Baker and the goal-partitioning procedure proposed by Freeland are here used as a foundation for developing an organizational system model.

Goodwin's Model of a Welfare System

Goodwin [50], inconsidering the welfare problem, recognizes six major groups, which he calls systems, interacting with one another. The donor group is comprised of persons who, "through legislation and appropriations, define and provide resources for meeting the problem" [50, p.86]. Nationally, the donor group would be the members of Congress and the Executive Office and locally it would be a board of commissioners. There is also a recipient group, which encompasses a definable set of persons--those on welfare--who are granted funds by and are subject to the requirements of the donor group. Two intermediary groups, the administrative group and delivery group, are recognized. The administrative group comprises persons charged with over-all responsibility for administering the various programs that will presumably solve the "problem." The delivery group consists of the people who interact with recipients and actually provide, under the guidelines of the administrative group, the services commissioned by the donor group. Two additional "groups" are mentioned, but not explicitly considered by Goodwin. These two "groups" are the job-environment, which involves the job market and other environmental factors that affect the employability of welfare recipients, and the constituency, which consists of the voting and tax-paying groups in society. Figure 1 presents Goodwin's model of the groups (systems) involved in the operation of a national public program. The cross-hatched areas represent official important interactions between persons in adjacent groups. As can be seen, no direct contact is assumed between the recipient group and the donor group.

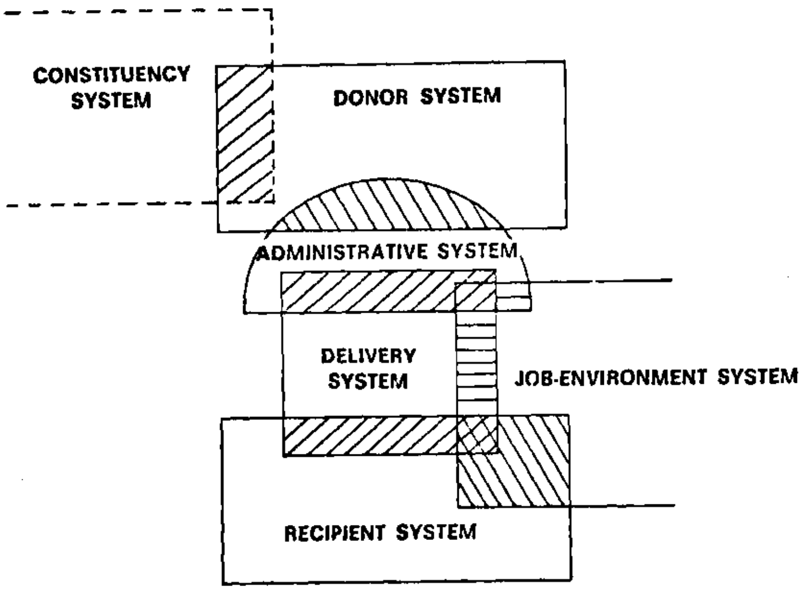


Figure 1. Systems Involved in Operation of a National Public Program [50, p.89]

Goodwin indicates, as presented in Figure 1, that recognition of the components and their interaction would be the first step in developing a model which accurately portrays the social problem-solving process. A second step would include the measurement and comparison of the goals and beliefs of the members of the different groups and the relationship they have to the actions of these groups. Goodwin then feels that it would be reasonable to undertake an experimental study to determine the impact of this information about the groups on the groups themselves.

In viewing the donor group, Goodwin emphasizes the varying amounts of influence that individuals in the group possess. In addition, there exist different and sometimes conflicting viewpoints in designing a welfare system based upon the conservative as opposed to the liberal stance. "Conservatives believe that increasing welfare payments would markedly decrease the productivity of our economic and social system" [50, p.90]. Thus conservative legislators appear to favor policies with strict work requirements and low payments. Liberal legislators, on the other hand, appear to favor higher welfare payments and oppose harsh work requirements. Thus, it is evident that within the donor system some form of negotiation or bargaining may occur before a set of goals or mandates is established.

Once mandates are determined, the two intermediary groups have the responsibility of effecting the donor's mandates. Goodwin implies that there are many ways in which an administrative group can fail to fulfill the goals of the donor system. "It may substitute goals, or it may organize operations on the basis of views that do not accurately portray events in the delivery, recipient, or job-environment systems" [50, p.93]. A closer inspection of the problem of failure leads one to realize that three major aspects need to be recognized: (1) the goals of the groups may be different; (2) the priorities associated with the goals may vary from group to group; and (3) perceptions of one group's goals by another group may be incorrect. Research by Korman [66] and Rosenberg [87] suggests that perceptions markedly affect not only interaction but also outcomes.

Goodwin proposes that members of the several groups should be brought together by and with researchers in order to confront the following empirical findings:

1. Influential persons in the donor and intermediary systems misperceive the positive orientation of the poor toward work.

2. Major blockages in the job-environment system prevent poor people from advancing in the work world.

3. Federal work-training efforts have had in the past very little success in helping welfare recipients enter the work force. [50, p.96.]

Goodwin suggests that such studies would aid in changing the views of members of different groups, which might lead toward altered policies and programs.

It is important to note that Goodwin has recognized the major components in the total system, their interactions and perceptions. In the next section, an analytical model of a service organization, proposed by Baker [7], is reviewed. It can be seen that the general interaction concepts and perceptions described by Goodwin can be formulated analytically.

Baker's Analytical Model of a Service Organization

Baker [7] specifies three classes of participants in the service organization: users, servicers, and funders. Users are those persons, who because of some need for service, have an opportunity to make use of the services offered by the service organization. Servicers are those persons who manage, operate, and maintain the service organization. Although Baker recognizes that servicers are composed of both administrative personnel and delivery personnel (in Goodwin's terms), he focuses primarily upon those servicers in the administrative system, that is, those who are responsible for determining policies and procedures.

Finally, the term "funders" refers to those persons who provide resources which enable the service organization to operate. Baker specifies that the funders typically reserve the right to evaluate the activities of the organization. He uses Blau and Scott's [20] definition of a service organization as "one whose prime beneficiary is the part of the public in direct contact with the organization, with whom and on whom its memberswork--in short, an organization whose basic function is to serve clients."

Drawing from operations research and organization theory, Baker develops general analytical models which describe user, servicer and funder behavior, both as separate entities and in interaction. Although Baker bases his models on the service organization, it appears that the model is general enough to encompass the welfare system described by Goodwin and termed a commonweal by Blau and Scott and also, with a slight change in definitions, the business concern. Due to this possible wide application of Baker's model to various types of organization, it is discussed in detail.

Based upon a series of hypotheses, Baker defines the primary considerations in the analytical model. Hypothesis 1 states that servicer behavior is goal directed. Let G be the set of servicer goals which can be partitioned into four subsets: G_s are the servicer-oriented goals, G_f are funder-oriented goals as perceived by the servicer, G_u are user-oriented goals as perceived by the servicer, and G_x are any goals not classified as user, funder or servicer oriented. Hypothesis 2 states that the funders have a set of criteria which they utilize in evaluating the performance of the service organization. Let C be the set of funder criteria which can be partitioned into four subsets C_s, C_f, C_u, C_x, where the subscripts s, f, u, and x carry the same meanings as for servicer goals except that they are perceived by the funder. Hypothesis 3 states that user behavior relative to the service organization is need directed, that is, the users have a set of needs and a set of expectations which guide their behavior relative to the service organization. Given a set of alternative sources of need satisfaction and a set of user needs related to the service organization, Baker hypothesizes that each user has an expectation of the rewards and costs associated with utilizing a particular source for satisfaction of one or more specific needs. Borrowing from the work of Thibaut and Kelly (1959), Baker proposes that the user has a standard or comparison level which is utilized in evaluating whether to start or continue with a particular source when one or more specific needs are present.

Before defining a decision problem for the servicers, some additional definitions are helpful.

1. $P = \{p_k;\ k=1,2,\ldots,s\}$ is a set of operating strategies, i.e. policies, practices,or projects, which are feasible for the servicers to utilize in operating the service organization.

2. $H(v_{ib_k})$ is the servicer objective function where v_{ib_k} is the contribution to the servicer from goal g_i if strategy p_k is utilized at a budget level b.

3. $M(w_{jb_k})$ is the funder evaluation where w_{jb_k} is the contribution to the funder from criterion c_j if strategy p_k is utilized at a budget level b.

4. $R(y_{lb_k})$ is the user need satisfaction function where y_l is the contribution to the user from need n_l if strategy p_k is utilized at a budget level b.

If a single resource, for example, money, is considered, the funders may influence or have control over (1) the total available amount of the single resource, B, (2) the maximum amount of the resource to be utilized by policy k, $\bar{B}_k$, and (3) the minimum amount to be appropriated to policy k, $\underline{B}_k$. In addition to the budgetary constraints, the funders may impose upon the servicers minimum levels of satisfaction of the funder evaluation function, β^f, and the user satisfaction function β^u, where β^f equals the minimum $M(w_{jb_k})$ which the funders view as satisfactory and β^u equals the minimum $R(y_{lb_k})$ which the funders view as satisfactory. Then the fully constrained servicer decision problem is:

$$\underset{b_k}{\text{Maximize}} \quad H(v_{ib_k}) \tag{3-1}$$

$$\text{such that} \quad 0 \le \underline{B}_k \le b_k \le \bar{B}_k \quad \text{for all } p_k \tag{3-2}$$

$$\sum_{k=1}^{s} b_k \le B \tag{3-3}$$

$$M(w_{jb_k}) \ge \beta^f \tag{3-4}$$

$$R(y_{lb_k}) \ge \beta^u \tag{3-5}$$

where b_k is the budget proposed for policy k.

Baker mentions that two extensions are straightforward. First, a multi-resource allocation, instead of a single resource allocation can be incorporated. Second, since allocations are often made over time, a multiple time period model can be used to consider the concept of time.

It is noted that the funders can exert control over the servicers by specification of the over-all budget, the minimum and maximum budget levels for specific operating policies, and minimum satisfaction levels β^f and β^u. However, as Baker mentions, the ability of the funders to exert control over the servicers is dependent upon their ability to act as one unit. Similarly, Goodwin indicates that the conflicting views of the liberals and conservatives of the donor group in establishing mandates are often resolved only after long debates in congressional committees.

In addition to exerting control over resources and specifying minimum satisfaction levels, Baker implies that the funders may attempt to modify the servicers' objective function by various methods of influence in order to increase agreement between G_f, G_u, and C_f, C_u, and the related v_{ib_k} and w_{ib_k}. Thus funders are seen as affecting servicer decisions by exerting control and/or exerting influence.

Although the problem thus far is seen as one in which the funders exert control or attempt influence and the servicers allocate resources within the constraints imposed, there is usually a two-way interaction between the funders and servicers in the budgeting process. Constraints are passed from the funders to the servicers, and in turn, proposed budgets are sent from the servicers to the funders. Thus, a re-evaluation may occur and the funders may change the constraints or the funders may approve the budgets. If constraints are changed, the new constraints are again passed to the servicers and the process repeats itself until a budget is approved.

Descriptions of this process of information flows during a budget establishment are given by Baker, Shumway, Maher, Souder and Rubenstein [8], and Shumway, et al. [95]. The authors describe the budget process as sequential in nature. Budget guidance flows from the highest administrative level through all intermediate levels to the lowest organizational levels. Each subordinate level then transmits a proposed budget allocation to the next higher level and the proposed budget allocations are aggregated and communicated to the next higher level until the highest level receives a proposed budget allocation. This process may be repeated until final approval is given by the top level.

The action of the user in the system may be determined by the type of organization and product or service offered. Of course the most common responses of a user are to use or not use a service, e.g., if the organization is a library, or to buy or not buy a product, e.g., if the organization is a business. However, other user responses may include demonstration, boycotts, civil rights marches, letters of complaint, dissatisfaction, or satisfaction to the organization or funders, or verbal complaints to the servicers or representatives of the organization. Baker considers direct and indirect methods of user influence, where direct influence refers to user-servicer interaction and indirect influence refers to user-funder interaction with user anticipation of influencing the servicers indirectly. Of course, the user may attempt direct influence, indirect influence or both simultaneously.

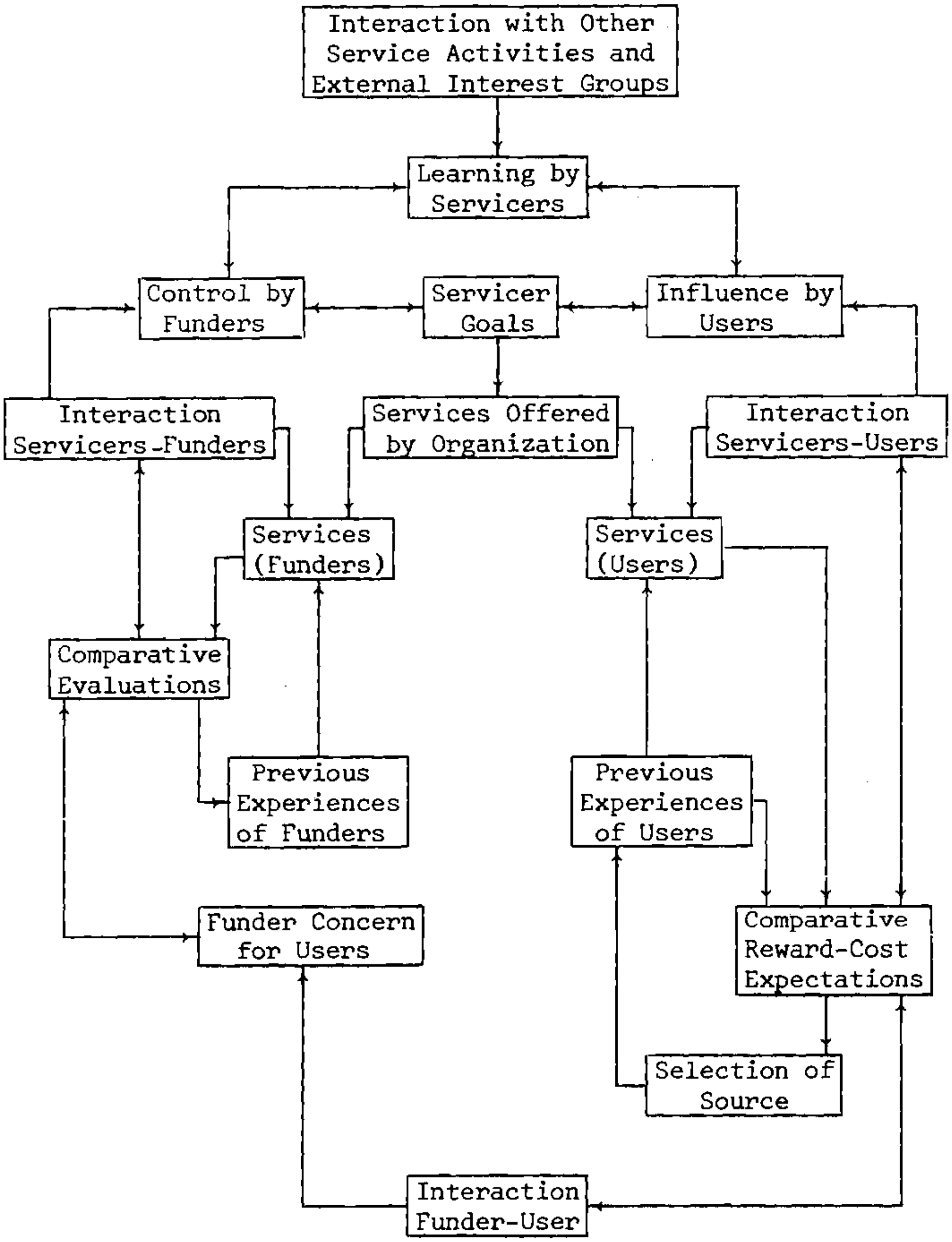
Also included in Baker's overall model of behavior are factors such as previous experiences of funders and users and learning by servicers. The over-all model is presented in Figure 2.

Ruefli's Generalized Goal Decomposition Model of Decision Making

Ruefli [91,89] has developed a generalized goal decomposition model which can be interpreted as a representation of decision making in a three-level hierarchical organization. It appears that the interaction process between funders and servicers in the budgeting process of Baker's model is similar in nature to the resource allocation process in Ruefli's model.

The hierarchical structure of the organization in Ruefli's process is shown in Figure 3. Depending upon the particular type of organization, the top level management may be termed the central unit, funders, donor group, or superordinate and these terms will be used interchangeably. The second level is assumed to consist of K management units, each having an individual who may be called an administrator, a manager, a servicer, or a director. Only the interaction between the two top levels is considered in relating the superordinate-administrator interaction, but it can be easily generalized to many levels.

In a manner analogous to the development of Baker's model, assume that administrator behavior is goal directed and that each goal is



where: ( ) is read "as perceived by."

Figure 2. Baker's Overall Model of Behavior

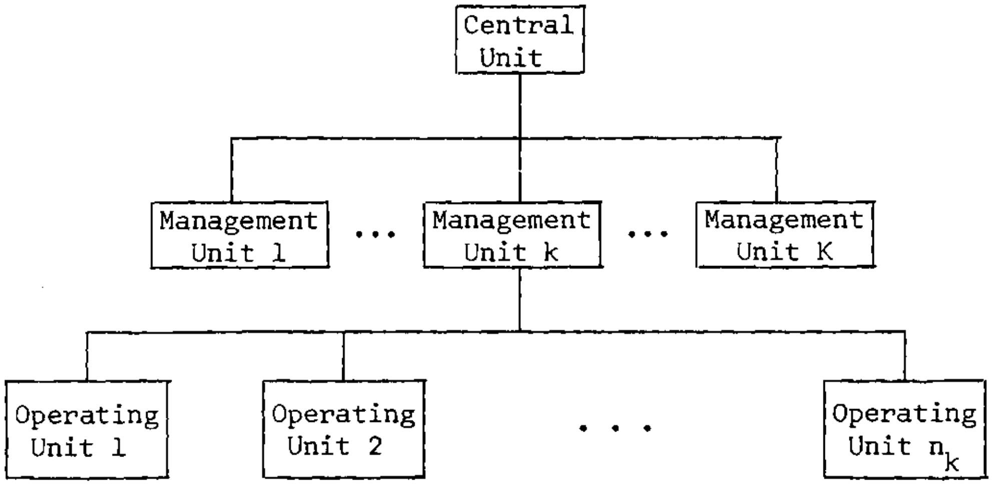


Figure 3. Ruefli's Model of a Hierarchical Organization

measurable. Let $\underline{g}_k$ be an $(m_k \times 1)$ vector of goal levels prescribed for administrator k by the superordinate. A component of $\underline{g}_k$, say g_{jk}, may indicate the requirement level or output that top management desires from unit k or it may indicate the amount of resource j available for input to unit k. For example, g_{1k} may represent the profit desired from unit k, g_{2k} may represent the proposed budget, and g_{3k} may be a limit on the manpower available to unit k. Thus, instead of a single resource model, a multiple resource--multiple requirement model can be attained. In addition, it is assumed that a project i of unit k can be described by an $(m_k \times 1)$ vector of attribute levels, $\underline{p}_{ik}$, where each attribute is directly related to a goal. Given n_k projects or policies to implement, the administrator would attempt to determine which ones to select and at what level they would be implemented. Let x_{ik} be the activity level (as a fraction of the proposed level) of the *ith* project of management unit k, that is, x_{ik} is allowed to vary between zero and one. At x_{ik} equal to one, project i of unit k would be fully implemented and its contribution toward the goals could be described by the vector $\underline{p}_{ik}$. Ruefli assumes a linear model and thus the contribution of project i of unit k toward the goals is simply $\underline{p}_{ik}x_{ik}$.

Given a set of goals or goal vector and a set of projects, each administrator would seek to determine the activity level for each project so that

$$\sum_{i=1}^{n_k} \underline{p}_{ik}x_{ik} = \underline{g}_k \quad \text{and} \quad 0 \le x_{ik} \le 1 \quad \text{for } i=1,2,\ldots,n_k \tag{3-6}$$

However, allowing for the possibility of not being able to exactly attain the goals, Ruefli describes the problem of the *kth* management unit as:

$$\min\ (\underline{w}_k^+\underline{d}_k^+ + \underline{w}_k^-\underline{d}_k^-) \tag{3-7}$$

$$\text{subject to } \sum_{i=1}^{n_k} \underline{p}_{ik}x_{ik} - I\underline{d}_k^+ + I\underline{d}_k^- = \underline{g}_k \tag{3-8}$$

$$0 \le x_{ik} \le 1 \quad \text{for } i=1,2,\ldots,n_k \tag{3-9}$$

$$\underline{d}_k^+ \ge \underline{0} \quad \text{and} \quad \underline{d}_k^- \ge \underline{0} \tag{3-10}$$

where $\underline{d}_k^+$ and $\underline{d}_k^-$ are $(m_k \times 1)$ column vectors of positive and negative deviations (respectively) from the goals; $\underline{w}_k^+$ and $\underline{w}_k^-$ are $(1 \times m_k)$ row vectors of weights associated with positive and negative deviations; and I is the identity matrix of appropriate dimension. The objective is to minimize the weighted sum of deviations from the goals.

The problem for the k*th* management unit is one in which the administrator attempts to attain the specified goal levels by determining the activity levels of the possible projects within the unit. It is assumed that priorities can be attached not only to the specific goals, but also to the deviations from the goal level.

The actual goal levels attained in management k's unit would be

$$\sum_i \underline{p}_{ik} x_{ik} = \underline{g}_k + I\underline{d}_k^+ - I\underline{d}_k^- . \tag{3-11}$$

Of course, for any particular goal, say j, it is easily seen that d_{jk}^+ and d_{jk}^- should not both be positive at the same time. The simplex procedure, which is used to solve the problem, incorporates this condition. Also, since they are required to be greater than or equal to zero, it follows that $d_{jk}^+ d_{jk}^- = 0$. If the actual goal level attained is equal to g_{jk}, then both d_{jk}^+ and d_{jk}^- equal zero.

It should be mentioned that the weights attached to the deviations need not be positive. For example, if a specific profit level is desired and any profit generated from the k*th* unit that is above the specified level is considered as desirable, the weight attached to the positive profit deviation could be negative. Then, in a minimization problem, it would be desirable to increase profits above the specified level since the negative weight would decrease the value of the objective function.

Ruefli proposes the use of the simplex algorithm to solve the problem of the k*th* management unit. Associated with the optimal solution to the problem for the k*th* unit is a $(1\times m_k)$ vector of simplex multipliers $\underline{\pi}_k$. The simplex multipliers or shadow prices can be interpreted as the change in the value of the k*th* unit's objective function per unit change in the right-hand side values. Thus, the j*th* component of $\underline{\pi}_k$, is the change in the objective function per unit change in the j*th* goal level.

Ruefli writes the problem of the central unit as:

$$\min \sum_{k=1}^{K} \underline{\pi}_k \underline{g}_k \tag{3-12}$$

$$\text{subject to } \sum_{k} P_k \underline{g}_k \geq \underline{G}_o \tag{3-13}$$

$$\underline{g}_k \geq \underline{0} \quad \text{for } k=1,2,\ldots,K \tag{3-14}$$

where $\underline{G}_o$ is a $(q\times 1)$ vector of stipulations or minimum acceptable levels and the P_k are $(q\times m_k)$ matrices which transform the unit goals into appropriate central unit goals.

Referring to duality theory (Dantzig, 1963), it can be stated that, at optimality, the objective function of the k*th* unit's problem, $\min(\underline{w}_k^+\underline{d}_k^+ + \underline{w}_k^-\underline{d}_k^-)$, is equal to max $\underline{\pi}_k\underline{g}_k$. Given that the central unit receives information regarding the optimal dual multipliers from each unit, the central unit is attempting to decrease the value of the sum of the objective functions of the units by changing their goals subject to the restriction of satisfying the central unit's goals.

In comparison to Baker's model, $\underline{g}_k$ may be seen to represent not only budget constraints but a number of other constraints in addition to specifying the desired outputs from unit k. The general objective function of the servicers is replaced by a specific objective function of minimizing the sum of weighted deviations from the goals. The range for the budget in Baker's model can be handled in the following way. Assume that the budget for the *kth* unit can range from $g_{2k} - b$ to $g_{2k} + a$, where a and b are positive. Since any budget in the range may be considered acceptable and outside the range as unacceptable, the portion of the problem relating to the budget can be stated mathematically as follows:

$$\min\ (Mz^{+} + My^{+}) \tag{3-15}$$

$$\text{subject to} \quad \sum_{i} p_{2ik}x_{ik} - d_{2k}^{+} + d_{2k}^{-} = g_{2k} \tag{3-16}$$

$$d_{2k}^{-} - z^{+} + z^{-} = a \tag{3-17}$$

$$d_{2k}^{-} - y^{+} + y^{-} = b \tag{3-18}$$

$$d_{2k}^{+},\ d_{2k}^{-},\ y^{+},\ y^{-},\ z^{+},\ z^{-} \geq 0 \tag{3-19}$$

where M is a large positive weight. Thus, if the positive deviation, d_{2k}^{+}, is greater than a, then z^{+} would need to be greater than zero and the objective function's value would be large. If the positive deviation is greater than zero and less than a, then z^- would be greater than zero, z^+ would be zero, and the value of the objective function would be zero since the weights associated with d_{2k}^+ and z^- are zero. The same reasoning holds for d_{2k}^-, y^+ and y^-. A solution would be considered acceptable only if the solution to the above problem were zero.

However, the above description of the problem and Baker's problem are different in the sense that Ruefli's model provides guidelines (goals) for overall unit activity, whereas Baker allows specific restrictions on projects. The specific restrictions can be handled in the Ruefli model by having the central unit specify the range for the activity level of a particular project. For example, if project i, at full implementation, would require a budget of $10,000 and the funders indicate an acceptable range between $2,500 and $7,500, then the activity vector x_{ik} would be restricted to the range .25 to .75.

If, in addition to representing the central unit's goals, $\underline{G}_o$ included minimum levels associated with client satisfaction as perceived by the central unit, the generalized goal decomposition model may be interpreted in light of Baker's more general model. Besides requiring minimum satisfaction levels, Ruefli suggests that the central unit or funders also seek to minimize the sum of weighted goal discrepancies. However, there is no allowance for influence of a client directly upon the management unit as suggested by Baker in Figure 2, but not included in his analytical model, and described by Goodwin.

Ruefli proposes the following iterative procedure in solving his problem. Initially, the central unit specifies $\underline{g}_k^1$, k=1,2,...,K such that constraints (3-13) and (3-14) are satisfied. These goals are given to the respective managers who solve their problem using the simplex method. The administrators then indicate to the central unit the amount that the value of their objective functions would change per unit change in the goals, that is, they pass up the $\underline{\pi}_k$'s, k=1,2,...,K. The central unit then solves its problem and sends down a new set of goals, $\underline{g}_k^2$, k=1,2,...,K, to the respective administrators. This process continues until the deviations from the management unit goals are at a minimum and no readjustment of goal levels on the part of the central unit will yield a net decrease in the deviations from the goal levels of the organization as a whole. Ruefli refers to proofs by Dantzig [33] and Dantzig, Orden and Wolfe [34] to show that the process will terminate in a finite number of steps.

One of the problems of Ruefli's solution procedure is that the administrators may have to take some convex combination of all the goal levels sent to them by the central unit, that is, if r sets of goals have been sent to the management unit, the final solution may require that the selected operating goal levels be equal to $\sum_{t=1}^{r} g_{-k}^{t} z_t$, where $\sum_{t=1}^{r} z_t = 1$ and $z_t \geq 0$ for t=1,2,...,r. Feeland (1973) points out that it is necessary, for overall optimality, that each management unit must take the same convex combination. Since each management unit solves its problem independently, there is nothing to force each management unit to take the same convex combination unless the central unit determines it or the management units act as a group. Thus, Ruefli's model does not allow the subordinates to operate independently.

> The final decision and the decision of which goals will be assigned to each subordinate is made by the subordinates acting as a group. In light of this interpretation, Ruefli's procedure is unappealing because it destroys the subordinates' independence [Freeland, p.152].

Freeland proposes a goal partitioning procedure based on the works of Benders [18] and Zangwill [110] which alleviates the difficulties inherent in Ruefli's model. Freeland's negotiation model of a non-cooperative organization is discussed in a latter section of this chapter.

Collomb's Goal-Interval Model of a Decentralized Organization

Collomb [30] recognizes two classes of criteria which have been assumed by the management literature to direct the firm's behavior: profit maximizing and satisficing. Profit maximizing has been discussed earlier. Satisficing, proposed by Simon [96], emphasizes that an organization does not attempt an almost endless search for an optimum, but if an alternative meets or exceeds a set of minimally satisfactory criteria and no need for improvement is felt, then the search process can be stopped. But Collomb notes:

> Even if it is true that the firm is not motivated enough to look for another solution, as soon as any satisfactory alternative has been found, the firm would nevertheless be able in many cases to recognize, within the set of satisfactory alternatives, a better one. Furthermore, the attainment of a result within the satisfactory interval is generally an incentive to change the interval itself for the following periods in the direction of a "better" result. And, over a number of periods this trend for improvement will influence the searching process itself, which will incorporate some idea of what an optimizing search would be even if it is not carried to the point of actually looking for the optimum [30, pp.12-13].

Another consideration when there exists multiple objectives is to find a set of efficient points or efficient operating strategies [76]. Given two objectives maximize $f_1(\underline{x})$ and maximize $f_2(\underline{x})$ where $\underline{x}$ is a vector specifying an operating strategy and $\underline{x}$ is contained in a set S, then an efficient point $\underline{x}_0 \in S$ has the following property:

There exist no $\underline{x}$ different from $\underline{x}_0$ and $\underline{x} \in S$ such that $f_1(\underline{x}) \geq f_1(\underline{x}_0)$ and $f_2(\underline{x}) \geq f_2(\underline{x}_0)$.

Given multiple objectives, an analyst would attempt to find the set of operating strategies X such that for any $\underline{x}_i \in X$, the above property holds. Having the set of efficient points does not, however, aid a decision maker in specifying an operating strategy, but only eliminates the strategies that should not be considered. Therefore, it is still necessary to determine trade-offs and establish priorities before a specific operating strategy is selected.

Collomb proposes that a mixture of an optimizing and satisficing model, which he terms a goal-interval-oriented model, is more appropriate for describing a firm's behavior. Extending a goal programming formulation [26], Collomb suggests that for each performance variable x_i, there be a series of target values g_i^j. And that the value of an objective function would depend upon the position of x_i among the g_i^j and possibly some deviations $x_i - g_i^j$ for certain values of j. In general, the problem becomes:

$$\min h(x_i^{j+}, x_i^{j-}) \qquad (3\text{-}20)$$

$$\text{subject to} \quad x_i - x_i^{j+} + x_i^{j-} = g_i^j, \quad j=1,\ldots,J_i;\ i=1,\ldots,n \qquad (3\text{-}21)$$

$$f_k(x_1,x_2,\ldots,x_n) \geq 0,\ k=1,2,\ldots,K \qquad (3\text{-}22)$$

$$x_i^{j+},\ x_i^{j-} \geq 0 \qquad (3\text{-}23)$$

Of course, for a meaningful solution, no two variables x_i^{j+}, x_i^{j-}, can be simultaneously non-zero. If it is assumed that h is pseudo-convex and that the constraints (3-22) form a convex set, then the problem is a convex programming problem. In his work, Collomb uses this "goal-interval-oriented" model to formulate a firm's behavior.

Noting the increasing trend toward decentralization in large firms, Collomb characterizes a decentralized organization in the following way: (1) operating decisions are made by the management of the decentralized unit without, in principle, interference of the senior management; (2) the management of the decentralized units work toward one or more goals assigned to him and is judged or rewarded according to the results measured against the objectives; (3) the central management restricts itself to planning the objectives of the whole firm and defining rules and setting objectives for the decentralized units; and (4) the central management does not have detailed information on the operations and constraints of each decentralized unit. Thus, in developing models of decentralized organizations, it is important to specify the information known at each level and the information flows.

Noting the use of transfer prices in decentralized firms, Collomb presents a review of and the difficulties associated with models of decentralization through prices. The review includes models by Koopmans [65], Charnes and Cooper [25], and Arrow and Hurwicz [6].

Turning to decentralized models, which make use of goals and objectives as well as prices, Collomb reviews the works of Charnes, Clower, and Kortanek's [26] pre-emptive goal formulation, Kornai and Liptak's [67] goal-allocation national planning model, and Ruefli's [91] three-level generalized goal decentralization model. With respect to Ruefli's model, described in the previous section, Collomb comments, "that a progressive organization in a competitive context, as a business firm usually is, could not be satisfied with minimizing internal tensions under satisficing constraints, and a more general goal-programming formulation could be required" [30, p.121]. This leads to the notion that the central unit desires not only to minimize the sum of the weighted deviations from the subordinates goals but also to attempt to achieve some specific goals of its own.

Using a linear model for convenience, Collomb develops a goal interval model which has the following assumptions:

1. goal interval oriented behavior is assumed at every level
2. the central unit has to satisfy some global constraints
3. the central unit has a goal vector which describes the overall goals of the firm
4. each management unit is assigned a goal vector by the central management
5. the objective function of the central unit is the minimization of the deviation of the actual performance of management units from the overall goals

6. the weights given to each assigned goal by the decentralized units are likely to be dependent upon both explicit preferences and policies of the central unit and subjective biases of the unit management, however weight changes are not considered in the model

7. the decentralized unit operates within a framework of assigned goals and technical constraints

8. if assigned goals are outside a certain "interval of attainability", their incentive power (i.e. weight in the objective function) is reduced.

Before stating Collomb's goal-interval model, the following additional definitions are needed:

Let $\underline{s}^+$ and $\underline{s}^-$ = $(q\times 1)$ column vectors of positive and negative deviations of actual performance from G_o.

$\underline{u}^+$ and $\underline{u}^-$ = $(1\times q)$ row vectors of positive and negative weights for the central unit.

The central unit's problem can be stated as:

$$\min \quad (\underline{u}^+\underline{s}^+ + \underline{u}^-\underline{s}^-) \tag{3-24}$$

$$\text{subject to} \quad \sum_k P_k(\underline{g}_k + \underline{d}_k^+ - \underline{d}_k^-) - \underline{s}^+ + \underline{s}^- = \underline{G}_o \tag{3-25}$$

$$\underline{g}_k,\ \underline{d}_k^+,\ \underline{d}_k^-,\ \underline{s}^+,\ \underline{s}^- \geq \underline{0} \tag{3-26}$$

where $\underline{G}_o$ has become the desired goal levels of the central unit, rather than the minimum levels. The other variables in the central unit's problem were defined in the statement of Ruefli's problem. The problem for unit k is stated as:

$$\min\ (\underline{w}_k^+\underline{d}_k^+ + \underline{w}_k^-\underline{d}_k^-) \tag{3-27}$$

$$\text{subject to}\quad \sum_i \underline{p}_{ik}x_{ik} - \underline{d}_k^+ + \underline{d}_k^- = \underline{g}_k \tag{3-28}$$

$$\underline{d}_k^+,\ \ \underline{d}_k^- \geq \underline{0} \tag{3-29}$$

$$x_{ik} \geq 0 \text{ for all } i \tag{3-30}$$

Collomb also allows the possibility of an equation which couples the variables of different units:

$$\sum_i \sum_k c_{ik}x_{ik} \geq H. \tag{3-31}$$

A "discouragement zone," where the incentive power is reduced if the actual performance is outside the range of full impact of the goal, is also taken into account. The model for the management unit is modified as:

$$\min\ [\underline{w}_k^+(\underline{d}_k^+ - a_k^+\underline{z}_k^+) + \underline{w}_k^-(\underline{d}_k^- - a_k^-z_k^-)] \tag{3-32}$$

$$\text{subject to}\quad \sum_i \underline{p}_{ik}x_{ik} - \underline{d}_k^+ + \underline{d}_k^- = \underline{g}_k \tag{3-33}$$

$$\sum_i \underline{p}_{ik}x_{ik} - \underline{z}_k^+ + \underline{\Delta} = (\underline{g}_k + \underline{b}_k^+) \tag{3-34}$$

$$\sum_i \underline{p}_{ik}x_{ik} + \underline{z}_k^- - \underline{\Delta}' = (\underline{g}_k - \underline{b}_k^-) \tag{3-35}$$

$$\underline{d}_k^+,\ \underline{d}_k^-,\ \underline{z}_k^+,\ \underline{z}_k^-,\ \underline{\Delta},\ \underline{\Delta}' \geq \underline{0} \tag{3-36}$$

$$x_{ik} \geq 0 \quad \text{for all } i \tag{3-37}$$

where

a_k^+ and a_k^- are given coefficients (between zero and one characterizing the intensity of the discouragement when actual performance is situated outside the range of full impact of the goal.

$(\underline{g}_k+\underline{b}_k^+)$ is the upper limit of the impact range.

$(\underline{g}_k-\underline{b}_k^-)$ is the lower limit of the impact range.

$\underline{z}_k^+$ is an $(m_k \times 1)$ vector of positive deviations above the upper limit of the impact range.

$\underline{z}_k^-$ is an $(m_k \times 1)$ vector of negative deviations below the lower limit of the impact range.

$\underline{\Delta}$ is an $(m_k \times 1)$ vector of negative deviations below the upper limit.

$\underline{\Delta}'$ is an $(m_k \times 1)$ vector vector of positive deviations above the lower limit.

Noting that the modified form does not introduce any mathematical difficulty, but only increases the complexity of the notation, Collomb does not use the modified form in his statement of the overall problem facing the firm.

Collomb writes the overall problem as follows:

$$\min \ (\underline{u}^+\underline{s}^+ + \underline{u}^-\underline{s}^-) \tag{3-24}$$

$$\text{subject to } \sum_k P_k(\underline{g}_k-\underline{d}_k^+ + \underline{d}_k^-) - \underline{s}^+ + \underline{s}^- = \underline{G}_o \tag{3-25}$$

$$\sum_i \sum_k c_{ik} x_{ik} \geq H \tag{3-31}$$

$$\sum_i \underline{p}_{ik} x_{ik} - \underline{d}_k^+ + \underline{d}_k^- = \underline{g}_k, \quad k=1,2,\ldots,K \tag{3-28}$$

$$\underline{\pi}_k \underline{p}_{ik} \leq 0, \quad i=1,2,\ldots,n_k \tag{3-38}$$

$$-\underline{\pi}_k \leq \underline{w}_k^+ \tag{3-39}$$

$$\underline{\pi}_k \leq \underline{w}^- \tag{3-40}$$

$$\underline{w}_k^+ \underline{d}_k^+ + \underline{w}_k^- \underline{d}_k^- \leq \underline{\pi}_k \underline{g}_k \tag{3-41}$$

$$\underline{d}_k^+, \ \underline{d}_k^- \geq \underline{0} \tag{3-29}$$

$$\underline{s}^+, \ \underline{s}^- \geq \underline{0} \tag{3-42}$$

$$\underline{g}_k \geq \underline{0} \tag{3-43}$$

$$x_{ik} \geq 0 \tag{3-30}$$

Recognizing that the only non-linear terms present are the $\underline{\pi}_k \underline{g}_k$, Collomb proposes an algorithm by Soland (1970) for the solution of separable non-convex programming problems to solve this problem.

One might note that constraints (3-38), (3-39), and (3-40) are the dual constraints to the management unit's problem and constraint

(3-41) requires that the solution to the primal problem of unit k be less than or equal to the dual problem. However, duality theory requires that a solution to the primal problem, a minimization problem, be greater than or equal to the solution to the dual problem, a maximization problem. Thus constraint (3-41) requires an optimal solution, with the equality holding for each management unit problem. Using the above argument, Freeland (1973) proves that Collomb is assuming that the overall objective function is to minimize the sum of the weighted discrepancies from the central unit's goals plus the sum of the weighted discrepancies from the management units' goals. Collomb's overall problem might be revised by eliminating constraints (3-38), (3-39), (3-40), and (3-41) and replacing the objective function by

$$\min \left[\underline{u}^{+}\underline{s}^{+}+\underline{u}^{-}\underline{s}^{-} + \sum_{k} (\underline{w}_{k}^{+}\underline{d}_{k}^{+}+\underline{w}_{k}^{-}\underline{d}_{k}^{-})\right]. \tag{3-44}$$

One of the drawbacks associated with the solution procedure proposed by Collomb is that all information about the various elements of the problem is required and a centralized solution procedure is used. The problem was originally presented in a decomposed form; however, by rewriting it in an overall form for solution, all of the information is required. Thus the method of solution is not feasible in an operational sense, in that it does not mirror the solution procedure in an organization. However, the model may be used to simulate the effect of changes in organizational parameters and for a centralized review of the organization.

Freeland's Negotiation Model of a Non-Cooperative Organization

With the belief that "conceptual models of organizational processes can provide insights and knowledge about how the flow of information and the organizational structure can affect decision making" [45, p.1], Freeland presents and analyzes mathematical models of resource allocation decision making in a hierarchical decentralized organization. Freeland views the organization as a goal-seeking system consisting of goal-seeking subsystems in which "it is assumed that the decision making process at a specific point in the organization can be modelled as the solution of a mathematical programming problem" [45, p.6]. The constraints of the programming problem are seen to represent perceived technological and other restrictions imposed on the decision.

Freeland defines a cooperative organization as one in which there may exist conflict among decision making units at a given level of the hierarchy over limited resources available; however, there does not exist conflict between levels over objectives. In a non-cooperative organization, there also exists conflict between levels over objectives.

Looking at coordination mechanisms, which are "devices by which the superordinate can influence the subordinate to seek a resource allocation program that furthers the objectives of the superordinate" [45, p.13], Freeland considers two classes: (1) goal intervention mechanisms and (2) constraint intervention mechanisms. Goal intervention refers to a superordinate's influence over the objective function of the subordinate. Freeland reviews the goal intervention models, often called pricing approaches, of Koopmans [65] and Arrow and Hurwicz [6] and the decomposition algorithms of Dantzig-Wolfe [35,36], Balas [9], Whinston [107], Hass [56], Jennergren [60], Lasdon and Schoeffler [70], Uzawa [105], and Lasdon [69]. Constraint intervention refers to a superordinate's control over the feasible decision region of the subordinate. Freeland reviews constraint intervention models, often called resource budgeting approaches. The economic and behavioral interpretations and implications for the three basic strategies (1) tangential approximation, (2) large step subgradient, and (3) piecewise approaches, which have been suggested by Geoffrion [46], along with a number of algorithms utilizing these approaches in their solution procedure are discussed. Other approaches examined are those of Kornai and Liptak [67] and Weitzman [106].

Two specific characteristics of coordination mechanisms are absolute coordination, which "refers to acts which influence the subordinates so that they find a resource allocation program which is optimal with respect to the superordinate's objective function" [45, p.14], and relative coordination, which refers to "acts which influence subordinates to find a solution which is 'satisfactory' but not necessarily optimal with respect to the objectives of the superordinate" [45, p.14].

Freeland shows that in the decomposition models to date, except for Ruefli's and Collomb's models, that the structure of the organization has no effect on the final solution, that the subordinates have no autonomy or influence on thefinal decision, and that relative coordination has no meaning in a cooperative organization.

Freeland introduces a third coordination mechanism, a negotiation mechanism called a goal partitioning procedure, for a non-cooperative organization in which the resource allocation does depend on the organization's structure and the final decision is influenced by the objectives of the superordinate and subordinates. The goal partitioning algorithm is based on Bender's partitioning procedure [18].

Freeland rewrites Ruefli's model as an overall problem:

$$\min \sum_k (\underline{w}_k^+ \underline{d}_k^+ + \underline{w}_k^- \underline{d}_k^-) \tag{3-45}$$

$$\text{subject to} \quad \sum_k P_k \underline{g}_k \geq \underline{G}_o \tag{3-46}$$

$$\sum_i \underline{p}_{ik} x_{ik} - I d_k^+ + I d_k^- - \underline{g}_k = \underline{0} \quad \text{for } k=1,2,\ldots,K \tag{3-47}$$

$$x_{ik} \leq 1 \quad \text{for } i=1,\ldots,n_k \quad k=1,\ldots,K \tag{3-48}$$

$$x_{ik} \geq 0,\ \underline{d}_k^+,\ \underline{d}_k^- \geq 0. \tag{3-49}$$

The model is then expanded to include goals that the subordinate establishes for himself and technological constraints and other restrictions that must be satisfied. Thus a bit more "realism" is introduced into the model by recognizing that the subordinates may desire to achieve objectives which differ from the goals specified by the superordinate.

Since the goal partitioning procedure is used as a solution procedure in the organizational system model, the details are discussed in the next chapter.

In this chapter, the welfare system provided an illustration of the organizational system model. The analytical model of a service organization illustrated a general analytical description of the decision problem facing the major participants in an organizational system. Ruefli's goal decomposition model is a specialization of Baker's general model. In the goal decomposition model, the funder is seen as attempting to minimize the overall internal tension of the organization by establishing goal guidelines for the administrators in addition to exceeding a threshold level for organizational requirements and allocating organizational resources which do not exceed their availability. Collomb extended the work of Ruefli by (1) allowing the central unit to have specific goal levels, instead of threshold levels, (2) allowing regions for satisfactory goal attainment and (3) providing for a discouragement zone when actual performance is outside the range of full impact of the goal. The goal partitioning solution procedure suggested by Freeland appears to present a more realistic description in a behavioral sense, of the resource allocation process in a hierarchical decentralized organization. However, Freeland's model does not explicitly include client interaction with the funder or administrator. In the next chapter, the goal partitioning procedure is described in light of client intervention. Thus the model will be expanded to reflect the interactions described in the models of Baker and Goodwin.

CHAPTER IV

DEVELOPMENT OF ORGANIZATIONAL DECISION SYSTEM MODELS

Introduction

In this chapter, several organizational decision system models of resource allocation in a hierarchical organization are proposed. First, a model, based upon Freeland's goal-partitioning procedure and Baker's analytical model of the resource allocation process in a service organization is developed along with a description of a solution procedure. In this model, the satisfaction of a client is reflected in the funder's perception of minimum satisfaction level of the client as described in Baker's model.

Next, two organizational system models, in which client feedback is explicitly included in the goal setting, planning, and resource allocation process, are proposed when the client is allowed to purchase portions of the organization's output. The first model describes one way in which the central unit could use client feedback to establish client-oriented goals for the management unit when deviations from the client-oriented goals are allowed. The second model considers the situation in which the management unit is not allowed to deviate from the client-oriented goals.

Consideration is given for allowing projects to be redesigned subject to technological constraints.

If the organization's output is such that the client is in a buy-no buy situation, then the types of information flow needed and the use of this information for producing output more acceptable to the client are discussed along with an information flow model.

A Goal Partitioning Procedure (Implicit Consideration of a Client)

Consider the two-level hierarchical organization, in which the central unit has some perception of the needs of the client as shown in Figure 4.

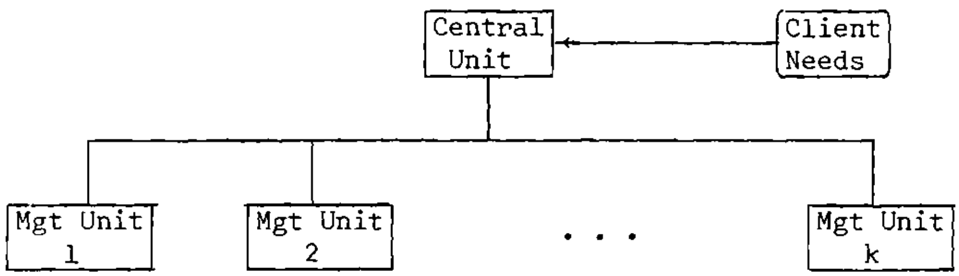


Figure 4. Two-Level Hierarchical Organization with Client Interaction

The superordinate, top management, or funder are considered as the central unit and have control over the allocation of resources and establishment of overall objectives. Assume that the central unit has established the organization's resource levels and organizational performance requirements and these levels can be described by a vector $\underset{\sim}{G}_f$ with dimension (q×1). For example, the first s components of $\underset{\sim}{G}$ may specify the levels of organizational resources available and the last (q-s) components may specify the minimum organizational performance requirements established by the central unit. In addition, assume that the central unit has some perception of the client's desires and is able to describe the organization's output in terms of a vector of output attributes and that the minimum attribute levels can be described by the vector $\underline{G}_c$ with dimension ($r \times 1$). Although the components of $\underline{G}_c$ could be considered as performance requirements specified by the central unit and thus be incorporated in $\underline{G}_f$, it is desirable to keep $\underline{G}_c$ and $\underline{G}_f$ distinct in order to develop a frame of reference for the models developed in this chapter.

The central unit's desire is to attempt to allocate organizational resources and organizational performance requirements and to determine the contribution to the organization's output for each management unit such that

1. the resources used by the management units do not exceed the supply.

2. the performance of the management units which contribute toward the organizational performance requirements at least satisfy the minimum organizational performance requirements.

3. the organizational output, which consists of the contributions of each management unit at least achieves the minimum attribute levels.

Let $\underline{\underline{g}}_k^f$ be an ($f \times 1$) vector of central unit oriented goals for management unit k which consists of both resources performance requirements for management unit k, k=1,2,...,K. P_k is defined as a ($q \times f$) matrix which relates $\underline{\underline{g}}_k^f$ to $\underline{G}_f$ by $P_k\underline{\underline{g}}_k^f$. The rows of P_k specify the linear combination of the components of $\underline{\underline{g}}_k^f$ which utilize an organizational resource or contribute toward an organizational performance requirements. For example, if the first component of $\underline{G}_f$ referred to the total organizational budget and the first three components of $\underline{g}_k^f$ referred to budgets available to management unit k for manpower, capital equipment, and raw resources, then the first row of P_k would consist of three 1's followed by (f-3) zero's. Considering resources as being negative in value and performance requirements positive in value and, for simplicity, assume that the consumption of organizational resources and achievement of organizational performance requirements is $\sum_k P_k \underline{g}_k^f$, then the central unit attempts to determine $\underline{g}_k^f$ for k=1,2,...,k such that $\sum_k P_k \underline{g}_k^f \geq \underline{G}_f$.

In a like manner, let $\underline{g}_k^c$ be a (c×1) vector of client-oriented objectives determined by the central unit for each management unit k, k=1,2,...,K and M_k be an (r×c) transformation matrix relating $\underline{g}_k^c$ to $\underline{G}_c$. The central unit, in seeking to satisfy the client, would want to specify client-oriented objectives $(\underline{g}_1^c, \underline{g}_2^c, \ldots, \underline{g}_k^c)$ such that $\sum_k M_k \underline{g}_k^c \geq \underline{G}_c$. (It may be the case that P_k and/or M_k are identity matrices). As with $\underline{G}_f$ and $\underline{G}_c$, the $\underline{g}_k^f$ and $\underline{g}_k^c$ are treated separately to develop a frame of reference for models developed in the main part of this chapter.

Given a vector of goals related to the central unit's objectives and to the client's objectives, administrator k is assumed to have the decision problem of determining the activity level x_{ik} for each project i, i=1,2,...,n_k, under his control. The activity level x_{ik} is a variable between zero and one, i.e. $0 \leq x_{ik} \leq 1$, for all i and k. A project is considered to be the smallest unit or task under the control of the administrator. It is assumed that each project can be described by a vector of project attributes $\underline{p}_{ik}$, dimension $\left((f+a_k+c+\ell_k)\times 1\right)$, where the subscript ik denotes the *ith* project of the *kth* unit.

In addition to central unit objectives $\underline{g}_k^f$ and client objectives $\underline{g}_k^c$ for each unit $k=1,2,\ldots,K$, it is desirable to denote two other goal vectors, which have been proposed by Freeland [44]. Let $\underline{g}_k^a$, an $(a_k\times 1)$ vector, be used to describe the goal levels desired by administrator k. These goals may consist of personal objectives of the administrator and objectives which are internal to the unit and do not concern top management. It is important to recognize these goals, since there may exist instances in which a subordinate may make decisions based, not upon satisfying organizational objectives, but rather upon achieving personal objectives of the administrator k or upon achieving objectives which are unique to management unit k. The last set of goal levels $\underline{g}_k^\ell$, an $(\ell_k\times 1)$ vector, refer to requirement levels based on exogenous factors, such as legal constraints or technological constraints. It is assumed that the requirement levels, based on exogenous factors, must be attained, whereas $\underline{g}_k^a$ refer to desirable goal levels for management unit k.

Given that management unit k has goals oriented toward the central unit $\underline{g}_k^f$, the client $\underline{g}_k^c$, exogenous factor $\underline{g}_k^\ell$, and itself $\underline{g}_k^a$, it is desirable to partition the vector of project attributes $\underline{p}_{ik}$. Thus, let $\underline{p}_{ik}^f$, $\underline{p}_{ik}^a$, $\underline{p}_{ik}^c$, and $\underline{p}_{ik}^\ell$ designate a project i's contribution toward the central unit's goals, management unit's personal goals, client-oriented goals, and exogenous goals, respectively.

In relating a project's contribution toward a management unit's goals, the following assumptions are made:

1. Project i's contribution toward the management unit's goals is a function of the activity level x_{ik} of that project.

2. Total contribution toward a management unit's goals is the sum of individual project contributions.

Assume that the goals levels for personal management unit goals and exogenous goals are fixed at $\underline{g}_k^a$ and $\underline{g}_k^\ell$, respectively, for k=1,2,..., K. Given that the central unit fixes $\underline{g}_k^f = \underline{g}_k^{ft}$ and $\underline{g}_k^c = \underline{g}_k^{ct}$ for each management unit such that $\sum_k P_k \underline{g}_k^{ft} \geq \underline{G}_f$ and $\sum_k M_k \underline{g}_k^{ct} \geq \underline{G}_c$, then, since it is usually assumed that the goals of a management unit should be met, the following vectors equations can be used to relate the projects, activity levels, and management unit's goals for management unit k:

$$\sum_i \underline{p}_{ik}^f(x_{ik}) = \underline{g}_k^{ft}$$

$$\sum_i \underline{p}_{ik}^a(x_{ik}) = \underline{g}_k^a$$

$$\sum_i \underline{p}_{ik}^c(x_{ik}) = \underline{g}_k^{ct}$$

$$\sum_i \underline{p}_{ik}^\ell(x_{ik}) \leq \underline{g}_k^\ell$$

The last vector row is in the form of an inequality in order to denote acceptability only for values less than or equal $\underline{g}_k^\ell$.

It is more often than not the case that the goals are either not attained or exceeded. To allow for this variation, let $\underline{d}_f^+$, $\underline{d}_a^+$, $\underline{d}_c^+$ be column vectors which indicate the amounts by which the respective goals are surpassed, that is, positive deviations, and $\underline{d}_f^-$, $\underline{d}_a^-$, $\underline{d}_c^-$ be column vectors which indicate the amounts by which the goals were not attained, that is, negative deviations. The above equations would then become:

$$\sum_i \underline{p}_{ifk}(x_{ik}) - \underline{d}^+_{fk} + \underline{d}^-_{fk} = \underline{g}^{ft}_k$$

$$\sum_i \underline{p}_{iak}(x_{ik}) - \underline{d}^+_{ak} + \underline{d}^-_{ak} = \underline{g}^{a}_k$$

$$\sum_i \underline{p}_{ick}(x_{ik}) - \underline{d}^+_{ck} + \underline{d}^-_{ck} = \underline{g}^{ct}_k$$

$$\sum_i \underline{p}_{i\ell k}(x_{ik}) \qquad\qquad \leq \underline{g}^{\ell}_k$$

where $\underline{d}^+_{fk}, \underline{d}^-_{fk} \geq \underline{0}$, $\underline{d}^+_{ak}, \underline{d}^-_{ak} \geq 0$, $\underline{d}^+_{ck}, \underline{d}^-_{ck} \geq \underline{0}$, and of course only the negative or positive component would be greater than zero. This last requirement is satisfied when using the simplex solution procedure.

In establishing an objective function for the administrator, the goal programming formulation is used. Since goals are usually set to be attained, it may be reasonable to assume that the administrator has the objective of meeting all of the goals of his unit. If this were the case, then a mathematical formulation of his objective function could be of the form:

$$\text{minimize} \quad (\underline{1}\underline{d}^+_{fk} + \underline{1}\underline{d}^-_{fk} + \underline{1}\underline{d}^+_{ak} + \underline{1}\underline{d}^-_{ak} + \underline{1}\underline{d}^+_{ck} + \underline{1}\underline{d}^-_{ck})$$

where $\underline{1}$ is a row vector (of appropriate dimension) of one's and the objective would be to minimize the sum of all positive and negative deviations by selecting the appropriate values for the activity levels.

If it is assumed that the measurement unit for the goals are expressed in a common dimension, then the above objective implies that an equal priority is attached to each deviation from a goal. However, the priority of a goal is usually established either explicitly or implicitly and there may exist a different amount of value attached to being below a specified goal level as opposed to exceeding that level. For example, an administrator may consider it to be highly important not to exceed a given budget level; however, he may also consider it to be fairly important not to spend an amount of money which is a great deal less than the budgeted level. If the latter case occurred, the administrator might find his budget cut during the next budgeting cycle and this is usually considered as an undesirable consequence.

In order to take into account the different priorities for positive and negative deviations and also the relative importance of these deviations with respect to deviations from other goals, let $\underline{w}_{fk}^{+}$, $\underline{w}_{ak}^{+}$, $\underline{w}_{ck}^{+}$ and $\underline{w}_{fk}^{-}$, $\underline{w}_{ak}^{-}$, $\underline{w}_{ck}^{-}$ be vectors of priorities associated with positive and negative goal deviations, respectively. The objective function for administrator k can then be written as:

$$\min \quad (\underline{w}_{fk}^{+}\underline{d}_{fk}^{+}+\underline{w}_{fk}^{-}\underline{d}_{fk}^{-}+\underline{w}_{ak}^{+}\underline{d}_{ak}^{+}+\underline{w}_{ak}^{-}\underline{d}_{ak}^{-}+\underline{w}_{ck}^{+}\underline{d}_{ck}^{+}+\underline{w}_{ck}^{-}\underline{d}_{ck}^{-})$$

The decision problem to be solved by administrator k is to determine the activity levels x_{ik} for each of the n_k projects under his control with the objective of minimizing the sum of weighted deviations from the established goal levels subject to the exogenous and technical constraints. The values of the weights are assumed to be determined by the administrator; however, the superordinate may exert some degree of influence in the selection of the values. As mentioned previously, the activity variables may vary from zero to one, where zero indicates that the project is rejected; one indicates that the project is fully implemented; and x_{ik} is strictly between zero and one indicates implementation at a partial level.

Assume, for convenience, that the project contributions are a linear function of activity level, that is, there are constant returns to scale, so that $\sum_i \underline{p}_{ik}(x_{ik}) = \sum_i \underline{p}_{ik} x_{ik}$. Given the fixed goal levels $\underline{g}_k^{ft}$ and $\underline{g}_k^{ct}$ from the central unit, management unit k's problem can now be formulated as a linear goal programming problem:

<u>Problem A_k^t</u>

$$\min \; z_k(\underline{g}_k^{ft}, \underline{g}_k^{ct}) = (\underline{w}_{fk}^{+}\underline{d}_{fk}^{+} + \underline{w}_{fk}^{-}\underline{d}_{fk}^{-} + \underline{w}_{ak}^{+}\underline{d}_{ak}^{+} + \underline{w}_{ak}^{-}\underline{d}_{ak}^{-} + \underline{w}_{ck}^{+}\underline{d}_{dk}^{+} + \underline{w}_{ck}^{-}\underline{d}_{ck}^{-}) \qquad (4\text{-}1)$$

$$\text{subject to} \quad \sum_i \underline{p}_{ik}^{f} x_{ik} - I\underline{d}_{fk}^{+} + I\underline{d}_{fk}^{-} = \underline{g}_k^{ft} \qquad (4\text{-}2)$$

$$\sum_i \underline{p}_{ik}^{a} x_{ik} - I\underline{d}_{ak}^{+} + I\underline{d}_{ak}^{-} = \underline{g}_k^{a} \qquad (4\text{-}3)$$

$$\sum_i \underline{p}_{ik}^{c} x_{ik} - Id_{ck}^{+} + I\underline{d}_{ck}^{-} = \underline{g}_k^{ct} \qquad (4\text{-}4)$$

$$\sum_i \underline{p}_{ik}^{\ell} x_{ik} \leq \underline{g}_k^{\ell} \qquad (4\text{-}5)$$

$$x_{ik} \geq 0 \quad \text{for } i=1,2,\ldots,n_k \tag{4-6}$$

where I is the identity matrix of appropriate dimension and $x_{ik} \leq 1$ is included in constraint (4-5) without loss of generality. The optimal value of the objective function of Problem A_k will be denoted $z_k^*(\underline{g}_k^{ft}, \underline{g}_k^{ct})$ and the optimal solution x_{ik}^t, $i=1,2,\ldots,n_k$.

Problem A_k is similar to Freeland's formulation with the addition of client-related goals and variables. Since the decision problem for management unit k is formulated as a linear programming problem, it can be solved by the simplex algorithm.

At this point it may be appropriate to recall that it is assumed that the goals of the administrator are commensorate, in that all goals may be transformed to a common dimension. However, Lee [73] strongly opposes such a transformation to a single criterion. He states:

> Often, multiple goals of management are in conflict or are achievable only at the expense of other goals. Furthermore, these goals are incommensurable. Thus, the solution of the problem requires an establishment of a hierarchy of importance among these incompatable goals so that the low-order goals are considered only after the higher-order goals are satisfied or have reached the point beyond which no further improvements are desired [73, p.21].

Lee suggests that the negative and/or positive deviations about a goal must be ranked according to preemptive priority factors. Preemptive priority factors (non-Archimedian weights) have the relationship of $W_j \ggg W_{j+1}$, which implies that the multiplication of W_{j+1} by n, no matter how large n may be, cannot make it larger than W_j. Lee proposes the use of a modified simplex algorithm which assures that high priority deviations are minimized before lower priority deviations are minimized.

This is accomplished by expanding the relative cost coefficient row in the simplex tableau to a matrix in which there is a row for each priority level. If deviational variables are commensurable, then they would have the same priority factor with possibly different coefficients to indicate the relative amount of unsatisfactory deviation from the goals. However, little is known about the dual problem and the meaning of the dual variables (which play an important part in the formulations and solution procedures suggested by Rueffli, Collomb and Freeland) when preemptive priority factors are used in the primal problem. Therefore, the discussion is continued assuming that the goals are commensurable.

In considering the objective function of administrator k, Collomb [30] has referred to it as a measure of internal tension and Freeland calls it discrepancy dissatisfaction. If $z_k^*(\underline{g}_k^{ft},\underline{g}_k^{ct})$ is the optimal value of Problem A_k^t when central unit and client goals are $\underline{g}_k^{ft}$ and $\underline{g}_k^{ct}$, respectively, then $z_k^*(\quad)$ could be considered as a measure of internal tension or discrepancy dissatisfaction. If, as Georgopoulos and Tannenbaum [48] suggest, one of the measures of effectiveness of an organization is the absence of strain or tension, then one of the objectives of the central unit might be to reduce the total amount of tension or dissatisfaction in the organization while attempting to insure that overall central unit objectives and client objectives are attained. Thus the central unit would attempt to select $(\underline{g}_k^{ft},\underline{g}_k^{ct})$, for k=1,2,..., K such that $\sum_k P_k\underline{g}_k^{ft} \geq \underline{G}_f$ and $\sum_k M_k\underline{g}_k^{ct} \geq \underline{G}_c$ and in addition minimize $\sum_k z_k(\underline{g}_k^{ft},\underline{g}_k^{ct})$ which is a reflection of the total amount of internal tension.

Following the work of Freeland (1973), the overall problem for the organization can be written as:

<u>Problem 0</u>

$$\min \sum_k z_k(\underline{g}_k^f, \underline{g}_k^c) = \sum_k (\underline{w}_{fk}^+ d_{fk}^+ + \underline{w}_{fk}^- \underline{d}_{fk}^- + \underline{w}_{ak}^+ \underline{d}_{ak}^+ + \underline{w}_{ak}^- \underline{d}_{ak}^- + \underline{w}_{ck}^+ \underline{d}_{ck}^+ + \underline{w}_{ck}^- \underline{d}_{ck}^-) \quad (4\text{-}7)$$

$$\text{subject to} \quad \left.\begin{aligned} \sum_i \underline{p}_{ik}^f x_{ik} - I\underline{d}_{fk}^+ + I\underline{d}_{fk}^- - I\underline{g}_k^f &= \underline{0} \\ \sum_i \underline{p}_{ik}^a x_{ik} - I\underline{d}_{ak}^+ + I\underline{d}_{ak}^- &= \underline{g}_{ak} \\ \sum_i \underline{p}_{ik}^c x_{ik} - I\underline{d}_{ck}^+ + I\underline{d}_{ck}^- - I\underline{g}_k^c &= \underline{0} \\ \sum_i \underline{p}_{ik}^\ell x_{ik} &\le \underline{g}_k^\ell \end{aligned}\right\} k=1,2,\ldots,K \quad (4\text{-}8)$$

$$\sum_k P_k \underline{g}_k^f \ge \underline{G}_f \quad (4\text{-}9)$$

$$\sum_k M_k \underline{g}_k^c \ge \underline{G}_c \quad (4\text{-}10)$$

$$\underline{d}_{kg}^+ \underline{d}_{fk}^- \ge \underline{0};\ \underline{d}_{ak}^+, \underline{d}_{ak}^- \ge 0;\ \underline{d}_{ck}^+, \underline{d}_{ck}^- \ge \underline{0};\ x_{ik} \ge 0 \quad \text{for all } i, k \quad (4\text{-}11)$$

One might note the similarity between Problem 0 and Baker's Single Resource-Fully Constrained Model, where $\underline{G}_f$ and $\underline{G}_c$ are analogous to the minimum level of satisfaction, β^f, of the funder evaluation function and the minimal level of user satisfaction, β^u, as perceived by the funder.

Before applying Benders' Partitioning Procedure [18] to the organization's problem, the following change in notation will aid in reducing the complicated notation.

Let

$$\underline{Y}_k = \begin{pmatrix} x_{1k} \\ x_{2k} \\ \vdots \\ x_{n_k k} \\ \hline \underline{d}^{+}_{fk} \\ \underline{d}^{-}_{fk} \\ \underline{d}^{-}_{ak} \\ \underline{d}^{-}_{ak} \\ \underline{d}^{+}_{ck} \\ \underline{d}^{-}_{ck} \end{pmatrix}; \quad \begin{aligned} \underline{W}_k &= (0,0,\ldots,0 \quad \underline{w}^{+}_{fk},\underline{w}^{-}_{fk},\underline{w}^{+}_{ak},\underline{w}^{-}_{ak},\underline{w}^{+}_{ck},\underline{w}^{-}_{ck}) \\ \underline{\pi}_k &= (\underline{\pi}^{f}_{k},\underline{\pi}^{a}_{k},\underline{\pi}^{c}_{k},\underline{\pi}^{\ell}_{k}) \end{aligned}$$

for k=1,2,...,K and define the following matrices:

$$F_k = [\underline{p}^{f}_{1k},\underline{p}^{f}_{2k},\ldots,\underline{p}^{f}_{n_k k} \quad -I \quad I \quad 0 \quad 0 \quad 0 \quad 0]$$

$$A_k = [\underline{p}^{a}_{1k},\underline{p}^{a}_{2k},\ldots,\underline{p}^{a}_{n_k k} \quad 0 \quad 0 \quad -I \quad I \quad 0 \quad 0]$$

$$C_k = [\underline{p}^{c}_{1k},\underline{p}^{c}_{2k},\ldots,\underline{p}^{c}_{n_k k} \quad 0 \quad 0 \quad 0 \quad 0 \quad -I \quad I]$$

$$L_k = [\underline{p}^{\ell}_{1k}, \underline{p}^{\ell}_{2k}, \ldots, \underline{p}^{\ell}_{n_k k} \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0]$$

and let the set of (g_k^f, g_k^c) be defined by

$$S = \{(\underline{g}_k^f, \underline{g}_k^c): \sum_k P_k \underline{g}_k^f \geq \underline{G}_f, \sum_k M_k \underline{g}_k^c \geq \underline{G}_c\}$$

Problem 0 can then be rewritten as:

Problem 0-1

$$\min \sum_k z_k(\underline{g}_k^f, \underline{g}_k^c) = \sum_k \underline{W}_k \underline{Y}_k \tag{4-12}$$

$$\text{subject to} \quad \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k - \begin{bmatrix} I\underline{g}_k^f \\ 0 \\ I\underline{g}_k^c \\ 0 \end{bmatrix} \begin{cases} = \underline{0} \\ = \underline{g}_k^a \\ = \underline{0} \\ \geq -\underline{g}_k^{\ell} \end{cases}, \quad k=1,2,\ldots,K \tag{4-13}$$

$$\underline{Y}_k \geq \underline{0} \quad k=1,2,\ldots,K \tag{4-14}$$

$$(\underline{g}_k^f, \underline{g}_k^c) \in S \tag{4-15}$$

For a fixed $(\underline{g}_k^f, \underline{g}_k^c) = (\underline{g}_k^{ft}, \underline{g}_k^{ct}) \in S$, the problem becomes

Problem O^t

$$\min \sum_k \underline{W}_k \underline{Y}_k \qquad (4\text{-}12)$$

$$\text{subject to} \quad \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^{ft} \\ = \underline{g}_{ak} \\ = \underline{g}_k^{ct} \\ \geq \underline{g}_k^{\ell} \end{cases}, \; k=1,2,\ldots,K \qquad (4\text{-}16)$$

$$\underline{Y}_k \geq 0, \quad k=1,2,\ldots,K \qquad (4\text{-}14)$$

However, with $(\underline{g}_k^f, \underline{g}_k^c)$ fixed, Problem O^t is separable into K problems:

Problem A_k^t for each $k=1,2,\ldots,K$

$$\min z_k(\underline{g}_k^{ft}, \underline{g}_k^{ct}) = \underline{W}_k \underline{Y}_k \qquad (4\text{-}17)$$

$$\text{subject to} \quad \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^{ft} \\ = \underline{g}_k^{a} \\ = \underline{g}_k^{ct} \\ \geq -\underline{g}_k^{\ell} \end{cases} \qquad (4\text{-}18)$$

$$\underline{Y}_k \geq \underline{0}. \qquad (4\text{-}19)$$

Let $\underline{\pi}_k = (\underline{\pi}_k^f, \underline{\pi}_k^a, \underline{\pi}_k^c, \underline{\pi}_k^\ell)$ be a $[1\times(f+a_k+c+\ell_k)]$ vector of dual variables for Problem A_k^t. The dual of Problem A_k^t can be written as

Dual D_k^t

$$\max\{\phi(\underline{\underline{g}}_k^{ft}, \underline{\underline{g}}_k^{ct}): \pi_k \epsilon U_k\} = \{\underline{\pi}_k^f \underline{\underline{g}}_k^{ft} + \underline{\pi}_k^a \underline{\underline{g}}_k^a + \underline{\pi}_k^c \underline{\underline{g}}_k^{ct} - \underline{\pi}_k^\ell \underline{\underline{g}}_k^\ell : \underline{\pi}_k \epsilon U_k\} \tag{4-20}$$

where

$$U_k = \left\{ \underline{\pi}_k : \underline{\pi}_k \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \le \underline{W}_k, \quad \underline{\pi}_k^\ell \ge \underline{0} \right\}$$

Problem 0 can then be written as:

$$\min_{(\underline{\underline{g}}_k^f, \underline{\underline{g}}_k^c) \epsilon R} \left[\sum_k \min[\underline{W}_k, \underline{Y}_k : \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{\underline{g}}_k^f \\ = \underline{\underline{g}}_k^a \\ = \underline{\underline{g}}_k^{ct} \\ \ge -\underline{\underline{g}}_k^\ell \end{cases}, \ \underline{Y}_k \ge \underline{0}] \right]$$

$$= \min_{(\underline{\underline{g}}_k^f, \underline{\underline{g}}_k^c) \epsilon R} \left[\sum_k \max[\underline{\pi}_k^f \underline{\underline{g}}_k^f + \underline{\pi}_k^a \underline{\underline{g}}_k^a + \underline{\pi}_k^c \underline{\underline{g}}_k^c - \underline{\pi}_k^\ell \underline{\underline{g}}_k^\ell : \underline{\pi}_k \epsilon U_k] \right]$$

where

$$R = \{(\underline{g}_k^f, \underline{g}_k^c) \epsilon S: \exists \text{ a feasible } \underline{Y}_k,\ k=1,2,\ldots,K \text{ to Problem 0}\}$$

$$= \{(\underline{g}_k^f, \underline{g}_k^c) \epsilon S: \text{ For each } \underline{\pi}_k \epsilon U_k,\ k=1,2,\ldots,K,$$

$$\max(\underline{\pi}_k^f \underline{g}_k^f + \underline{\pi}_k^a \underline{g}_k^a + \underline{\pi}_k^c \underline{g}_k^c - \underline{\pi}_k^\ell \underline{g}_k^\ell) < \infty\}$$

$$= \{(\underline{g}_k^f, \underline{g}_k^c) \epsilon S: \text{ For each extreme ray } \underline{\pi}_k^{r_k} \text{ of}$$

$$U_k,\ k=1,2,\ldots,K,\quad (\underline{\pi}_k^{fr_k} \underline{g}_k^f + \underline{\pi}_k^{ar_k} \underline{g}_k^a + \underline{\pi}^{cr_k} \underline{g}_k^c - \underline{\pi}_k^{\ell r_k} \underline{g}_k^\ell) \leq 0\}$$

The Problem 0 can further be expressed as:

<u>Problem 0-2</u>

$$\min \sum_k \sigma_k \tag{4-21}$$

$$\text{subject to} \quad \sigma_k \geq \max_{\underline{\pi}_k \epsilon U_k} [\underline{\pi}_k^f \underline{g}_k^f + \underline{\pi}_k^a \underline{g}_k^a + \underline{\pi}_k^c \underline{g}_k^c - \underline{\pi}_k^\ell \underline{g}_k^\ell] \tag{4-22}$$

$$\text{for } k=1,2,\ldots,K$$

$$(\underline{g}_k^f, \underline{g}_k^c) \ \epsilon\ R. \tag{4-23}$$

Note that for a particular $(\underline{g}_k^f, \underline{g}_k^c) = (\underline{g}_k^{ft}, \underline{g}_k^{ct})$, if there is an extreme ray $\underline{\pi}_k^r$ with

$$\underline{\pi}_k^{fr_k} \underline{g}_k^{ft} + \underline{\pi}_k^{ar_k} \underline{g}_k^a + \underline{\pi}_k^{cr_k} \underline{g}_k^{ct} - \underline{\pi}_k^{\ell r_k} \underline{g}_k^\ell > 0,$$

then the dual problem Dual D_k^t is unbounded for some $\underline{\pi}_k = \underline{\pi}_k^{S_k} + \lambda\underline{\pi}_k^{r_k}$, ($\lambda > 0$ and $\underline{\pi}_k^{S_k}$ an extreme point of Dual D_k^t). That is, Problem 0 has no feasible solution for $(\underline{g}_k^f, \underline{g}_k^c) = (\underline{g}_k^{ft}, \underline{g}_k^{ct})$. Hence the restriction $(\underline{\pi}_k^{fr_k}\underline{g}_k^f + \underline{\pi}_k^{ar_k}\underline{g}_k^a + \underline{\pi}_k^{cr_k}\underline{g}_k^c - \underline{\pi}_k^{\ell r_k}\underline{g}_k^\ell) \le 0$ is included in the definition of R.

Letting $\underline{g}_k = \begin{pmatrix} \underline{g}_k^f \\ \underline{g}_k^a \\ \underline{g}_k^c \\ -\underline{g}_k^\ell \end{pmatrix}$, Problem 0-2 can be expressed as

<u>Problem 0-3</u>

$$\min \sum_k \sigma_k \tag{4-21}$$

$$\text{subject to} \quad \sigma_k \ge \underline{\pi}_k^{S_k}\underline{g}_k, \quad S_k=1,2,\ldots,E_k, \quad k=1,2,\ldots,K \tag{4-24}$$

$$\underline{\pi}_k^{r_k}\underline{g}_k \le 0, \quad r_k=1,2,\ldots,H_k, \quad k=1,2,\ldots,K \tag{4-25}$$

$$\sum_k P_k\underline{g}_k^f \ge \underline{G}_f \quad \text{and} \quad \sum_k M_k\underline{g}_k^c \ge \underline{G}_c, \tag{4-26}$$

where S_k denotes an extreme point of Dual D_k of which there are E_k and r_k denotes an extreme ray of Dual D_k of which there are H_k. However, the rows of this problem can be generated as and when required. The solution procedure is given below. Proofs that the solution procedure given below is finite (that is, will terminate in a finite number of iterations), and is optimal (that is, solves Problem 0) are given by Benders [18, p.245] and Lasdon [69, p.379], when the set S is closed and bounded.

The solution procedure for solving Problem 0 is as follows:

Step 1. Select initial $\underline{g}_k^f = \underline{g}_k^{f1}$ and $\underline{g}_k^c = \underline{g}_k^{c1}$ for k=1,2,...,K, such that (4-26) is satisfied. Set initial $\sigma_k = \sigma_k^1 = -\infty$ for k=1,2,..., K. There are no constraints of the forms (4-24) or (4-25) present. This initial step is performed by the central unit. The $(\underline{g}_k^{f1}, \underline{g}_k^{c1})$ for k=1,2,...,K is sent to the respective management unit.

Step 2. Each management unit receives $(\underline{g}_k^{f1}, \underline{g}_k^{c1})$ from the central unit and solves Dual D_k^1 to yield an optimal extreme point solution $\underline{\pi}_k^{S_k 1}$ or an unbounded solution $(\underline{\pi}_k^{S_k 1} + \lambda \pi_k^{r_k 1})$. This solution is sent to the central unit.

Step 3. If there is an optimal extreme point solution for management unit k's problem, then it is greater than $-\infty$ (the value of σ_k^1) and constraint (4-24) is violated. Therefore the constraint is added and the dual simplex can be used. (Note that this requires the central unit to have information regarding the values of $\underline{\pi}_k^{S_k}$, $\underline{g}_k^a$, and $\underline{g}_k^\ell$. A method, proposed by Freeland (1973) is used to decrease the amount of information transferred and is discussed shortly.) If there is an unbounded solution for management unit k's problem, then it violates (4-25). In this case the constraint is added and the dual simplex can be used.

Step 4. After adding constraints of the form (4-24) and/or (4-25), Problem 0-3 is solved to attain σ_k^2 and $(\underline{g}_k^{f2}, \underline{g}_k^{c2})$ for k=1,2,..., K. The new set of goals are sent to the respective management unit and replace the previous $(\underline{g}_k^{f1}, \underline{g}_k^{c1})$. Management unit k solves Problem A_k^2. Again the extreme point solution or unbounded solution is sent to the central unit.

Step 5. At iteration T, if there is an unbounded solution, it violates constraint (4-25) and the constraint is introduced, and return to Step 4.

At iteration T, if there is an extreme point solution and constraints of the form (4-24) are violated, introduce the constraints and return to Step 4.

At iteration T, if there is an extreme point solution and constraints of the form (4-24) are *not* violated, then the solution is optimal for Problem 0.

If constraints of the form (4-24) are required, Freeland [45] presents a method in which it is not necessary to transfer the values of $\underline{\pi}_k^{aS_k}$ to the central unit. However, if constraints of the form (4-25) are required, then it is necessary to transfer the values of $\underline{\pi}_k$ to the central unit, which is undesirable from a behavioral standpoint, since the central unit has no control over administrator-oriented goals or technological factors. Extreme rays associated with constraint (4-25) need not be considered if the following assumption is made:

<u>Assumption 4-1</u>. Assume that a feasible solution exists to Dual D_k^t and the constraint set U_k is strictly bounded. Then the maximum value of Dual D_k^t occurs at an extreme point of the constraint set U_k and no extreme rays would exist.

Another way to alleviate constraint (4-25) of Problem 0-3 is by making the following assumptions: a feasible solution exists for

Problem A_k^t and there is a finite lower bound on the objective function $z_k(\underline{g}_k^{ft},\underline{g}_k^{ct})$ for Problem A_k^t for any choice of $\underline{g}_k^{ft} < \infty$, $\underline{g}_k^{ct} < \infty$. Then two duality theorems presented by Dantzig (1963) can be used.

Theorem 4.1. If a feasible solution exists for the primal Problem A_k^t and $z_k(\underline{g}_k^{ft},\underline{g}_k^{ct})$ has a finite lower bound, an optimal feasible solution exists.

Theorem 4.2. If an optimal feasible solution exists for the primal Problem A_k^t, there exists an optimal feasible solution to the dual, Dual D_k^t. The proofs are given by Dantzig [33, p.135].

Therefore, if it can be assumed that a feasible solution exists for the primal Problem A_k^t and it has a finite lower bound, and since an optimal feasible solution to the dual Dual D_k^t occurs at an extreme point, there would not exist any extreme rays and constraints of form (4-25) do not need to be considered.

Recognizing that there are a finite number of extreme points, $S_k=1,2,\ldots,E_k$ for Dual D_k^t, $k=1,2,\ldots,K$, Freeland [45] proposes the following approach in order to reduce the amount of information transfer required to solve Problem $\mathcal{Q}$.

For any given values $\underline{g}_k^{ft} < \infty$, $\underline{g}_k^{ct} < \infty$, at optimality, duality theory (Dantzig, 1963) states that the value of the primal Problem A_k^t $\left(z_k^*(\underline{g}_k^{ft},\underline{g}_k^{ct})\right)$ and the value of the dual Dual D_k^t $\left(b_k^*(\underline{g}_k^{ft},\underline{g}_k^{ct})\right)$ are equal. Therefore

$$z_k^*(\underline{g}_k^{ft},\underline{g}_k^{ct}) = \underline{\pi}_k^{ft}\underline{g}_k^{ft} + \underline{\pi}_k^{at}\underline{g}_k^{a} + \underline{\pi}_k^{ct}\underline{g}_k^{ct} - \underline{\pi}_k^{\ell t}\underline{g}_k^{\ell} \qquad (4\text{-}27)$$

where $(\underline{\pi}_k^{ft},\underline{\pi}_k^{at},\underline{\pi}_k^{ct},\underline{\pi}_k^{\ell t})$ denotes the optimal extreme point solution to Dual D_k^t. If the management unit k solves Problem A_k^t by using the simplex algorithm, the values of $z_k^*(\underline{\underline{g}}_k^{ft},\underline{\underline{g}}_k^{ct})$ and $(\underline{\pi}_k^{ft},\underline{\pi}_k^{at},\underline{\pi}_k^{ct},\underline{\pi}_k^{\ell t})$ are readily available. However, by sending only the values of $z_k^*(\underline{\underline{g}}_k^{ft},\underline{\underline{g}}_k^{ct})$, which may be considered as the amount of discrepancy dissatisfaction on interval tension, and $(\underline{\pi}_k^{ft},\underline{\pi}_k^{ct})$ which provide an indication of how $z_k^*(\underline{\underline{g}}_k^{ft},\underline{\underline{g}}_k^{ct})$ would change per unit change of the goals, enough information is available for the central unit to form a constraint of the form (4-24). This is accomplished by using the following constraint:

$$\sigma_k \geq z_k^k(\underline{\underline{g}}_k^{ft},\underline{\underline{g}}_k^{ct}) - \underline{\pi}_k^{ft}\underline{\underline{g}}_k^{ft} - \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{ct} + \underline{\pi}_k^{ft}\underline{\underline{g}}_k^{f} + \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{c} \tag{4-28}$$

which, by direct substitution of (4-27) is equal to

$$\sigma_k \geq \pi_k^{ft}\underline{\underline{g}}_k^{f} + \underline{\pi}_k^{at}\underline{\underline{g}}_k^{a} + \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{c} - \underline{\pi}_k^{\ell t}\underline{\underline{g}}_k^{\ell} \tag{4-29}$$

Constraint (4-28) and (4-24) are equivalent and the substitution is appropriate since $\underline{\underline{g}}_k^{a}$ and $\underline{\underline{g}}_k^{\ell}$ are not variables from the point of view of the central unit. The only goal variables for the central unit are $\underline{\underline{g}}_k^{f}$ and $\underline{\underline{g}}_k^{c}$. Using Assumption 1, which alleviates extreme rays, and constraint (4-28), Problem 0-3 becomes

Problem 0-4

$$\min \sum_k \sigma_k \tag{4-21}$$

subject to

$$\sigma_k \geq z_k^*(\underline{g}_k^{fS_k}, \underline{g}_k^{cS_k}) - \underline{\pi}_k^{fS_k} \underline{g}_k^{fS_k} - \underline{\pi}_k^{cS_k} \underline{g}_k^{gS_k} - \underline{\pi}_k^{cS_k} \underline{g}_k^{f} + \underline{\pi}_k^{cS_k} \underline{g}_k^{c} \tag{4-28}$$

$$\text{for } S_k=1,2,\ldots,E_k, \quad k=1,2,\ldots,K$$

$$\sum_k P_k \underline{g}_k^f \geq \underline{G}_f \quad \text{and} \quad \sum_k M_k \underline{g}_k^c \geq \underline{G}_c \tag{4-26}$$

where $(\underline{g}_k^{fS_k}, \underline{g}_k^{cS_k})$ are the values used in Problem A_k^t which determine $(\underline{\pi}_k^{fS_k}, \underline{\pi}_k^{cS_k})$.

Freeland's proposal has behavioral appeal in that the management unit provides only the amount of internal tension given goals $\underline{g}_k^{ft}$ and $\underline{g}_k^{ct}$ and an indication of how this amount of tension would change per unit change in the goal levels.

Given Assumption 1, the solution procedure for solving Problem 0 would be as follows:

Step 1. The Central unit arbitrarily selects goal levels $\underline{g}_k^f = \underline{g}_k^{f1} < \infty$ and $\underline{g}_k^c = \underline{g}_k^{c1} < \infty$ for $k=1,2,\ldots,K$ such that $\sum_k P_k \underline{g}_k^f \geq \underline{G}_f$ and $\sum_k M_k \underline{g}_k^c \geq \underline{G}_c$. Initially $\sigma_k = \sigma_k^1 = -\infty$ for $k=1,2,\ldots,K$. There are no constraints of the form (4-28) present. The $(\underline{g}_k^{f1}, \underline{g}_k^{c1})$ for $k=1,2,\ldots,K$ is sent to the respective management unit.

Step 2. Each management unit receives $(\underline{\underline{g}}_k^{f1}, \underline{\underline{g}}_k^{c1})$ from the central unit and solves Problem $\bar{A}_k^1$ and determines the optimal value of the objective function $z_k^*(\underline{\underline{g}}_k^{f1}, \underline{\underline{g}}_k^{c1})$ and $\underline{\pi}_k^{f1}$ and π_k^{c1}. This information is sent to the central unit. Due to Assumption 1, the value of the objective function of Dual D_k^1 is finite and equal to the value of the objective function of Problem A_k^1. Therefore the value of the objective function of Problem A_k^1 is finite and $z_k^*(\underline{\underline{g}}_k^{f1}, \underline{\underline{g}}_k^{c1}) > -\infty$.

Step 3. Since $z_k^*(\underline{\underline{g}}_k^{f1}, \underline{\underline{g}}_k^{c1}) > \sigma_k^1 = -\infty$, the central unit adds a constraint of the form (4-28) for each management unit k=1,2,...,K to Problem 0-4 and solves Problem 0-4 with one constraint (4-28) corresponding to the first extreme point for each management unit. The solution of Problem 0-4 yields $(\underline{\underline{g}}_k^{f2}, \underline{\underline{g}}_k^{c2})$ and σ_k^2 for k=1,2,...,K which are sent to the respective management unit.

At iteration T-1

Step 4. The central unit would solve Problem 0-4 with (T-1) constraints of the form (4-28) for each management unit:

$$\min \sum_k \sigma_k$$

$$\text{subject to} \quad \sigma_k \geq z_k^*(\underline{\underline{g}}_k^{ft}, \underline{\underline{g}}_k^{ct}) - \underline{\pi}_k^{ft} \underline{\underline{g}}^{ft} - \underline{\pi}_k^{ct} \underline{\underline{g}}_k^{ct} + \underline{\pi}_k^{ft} \underline{\underline{g}}_k^{f} + \underline{\pi}_k^{ct} \underline{\underline{g}}_k^{c}$$

$$\text{for } t=1,2,\ldots,T-1,$$

$$k=1,2,\ldots,K$$

$$\sum_k P_k \underline{g}_k^f \geq \underline{G}_k \quad \text{and} \quad \sum_k M_k \underline{g}_k^c \geq \underline{G}_c$$

The resulting optimal values σ_k^T and $(\underline{g}_k^{fT}, \underline{g}_k^{cT})$ are found and $(\underline{g}_k^{fT}, \underline{g}_k^{cT})$ is sent to management unit K.

Step 5. The management unit solves Problem A_k^T and the values $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{CT})$, $\underline{\pi}_k^{fT}$ and $\underline{\pi}_k^{cT}$ are sent to the central unit.

Step 6. The central unit checks to determine if any $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT}) > \sigma_k^T$ for k=1,2,...,K. If an inequality exists, then a constraint of the form (4-28) is added. Return to Step 4. If $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT}) \leq \sigma_k^T$ for k=1,2,..,K, then stop. An optimal solution has been found for Problem O.

Proof that the above iterative procedure will terminate in a finite number of iterations with an optimal solution to Problem O is given by Lasdon [69, p.379]. The solution is optimal in that the final values, which are selected by the central unit, for central unit-oriented goals and client-oriented goals for each management unit, and which are selected by the management unit for the project activity levels, minimize the objective function of Problem O. Therefore the objective of minimizing internal tension, suggested by Georgopoulos and Tannenbaum [49], would be satisfied.

The actual outputs from each management unit related to central unit goals and client goals at optimality are given by

$$\sum_i \underline{p}_{ik}^f x_{ik}^T = \underline{g}_k^{fT} + \underline{d}_{fk}^{+T} - \underline{d}_{fk}^{-T}$$

and

$$\sum_i \underline{p}_{ik}^{c} x_{ik}^{T} = \underline{g}_k^{cT} + \underline{d}_{ck}^{+T} - \underline{d}_{ck}^{-T}.$$

Thus, it should be mentioned that the final solution may not satisfy the minimal levels of satisfaction of the funder and client ($\underline{G}_f$ and $\underline{G}_c$). This occurs because there is no assurance that the administrators will select final activity levels x_{ik}^{T} such that

$$\sum_k P_k(\sum_i \underline{p}_{ik}^{f} x_{ik}^{T}) \geq \underline{G}_f \quad \text{or} \quad \sum_k M_k(\sum_i \underline{p}_{ik}^{c} x_{ik}^{T}) \geq \underline{G}_c$$

is satisfied. "This effect shows that the superordinate is either unwilling or unable to force the subordinates to meet all of the superordinate's goals" [Freeland, p.178]. However, if a specific goal of the funder must be met, it is conceivable that the funder will attempt to influence each administrator so that the priorities attached to deviations from the goal guideline are extremely large which would imply that the administrator would undergo a great deal of tension if the goal were not met.

A flow diagram of the goal partitioning procedure with an implicit consideration of the client's minimal satisfaction levels is illustrated in Figure 5.

The above process includes only the interaction between a superordinate and his administrators and, as such, is a direct extension of Freeland's work. The client's minimal satisfaction level is introduced as it is perceived by the superordinate. The next section considers

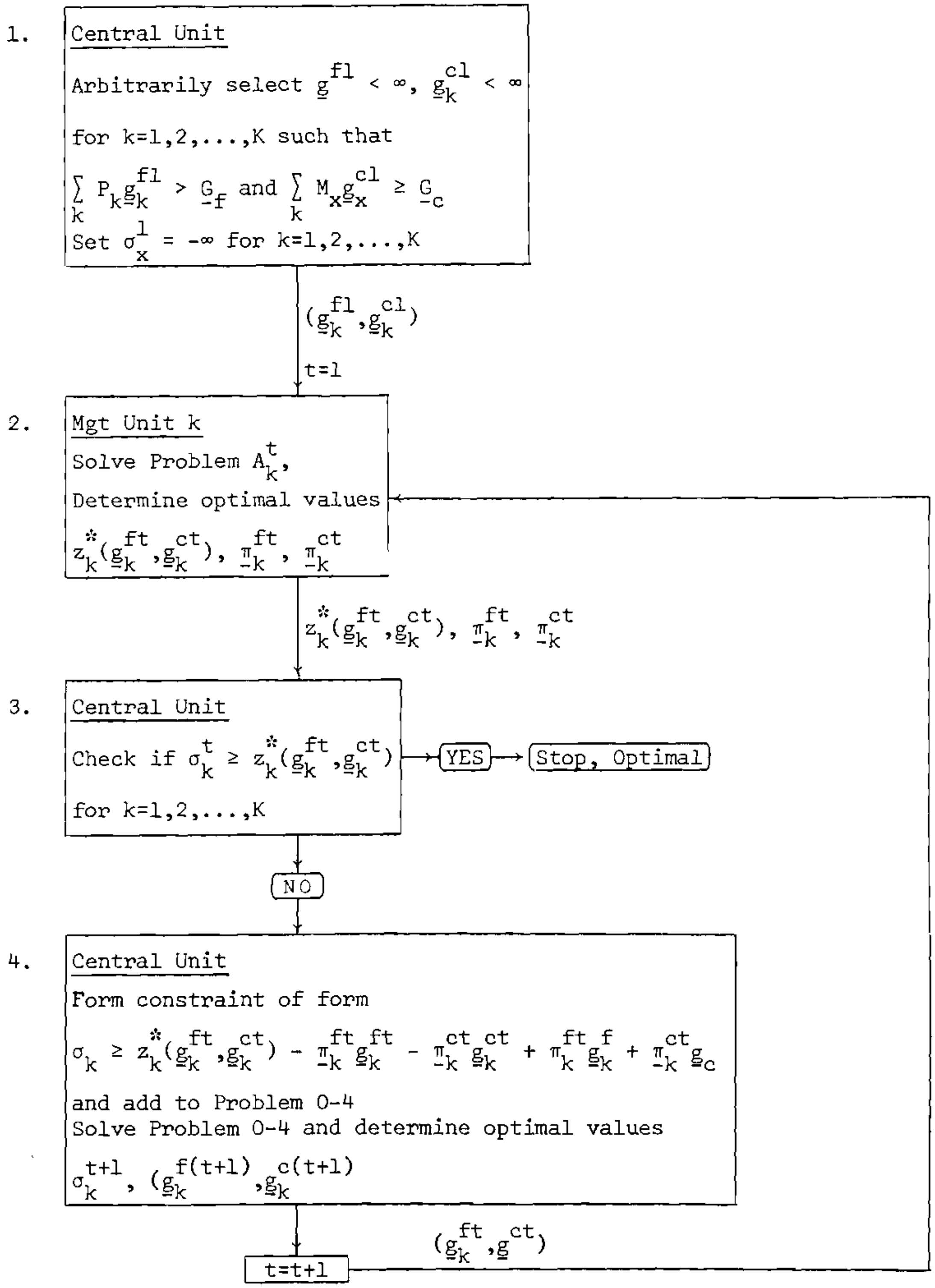


Figure 5. Information Flow Diagram of Goal Partitioning (Implicit Consideration of a Client)

how the client's needs and desires can be explicitly introduced into the system.

Explicit Consideration of a Client

In this section and the following sections, the client is seen as an integral part of the planning process of the organization. Rather than assumming that the central unit has a perception of only minimal client satisfaction levels, it is assumed that the client interacts with the organization and provides information based upon his needs, desires and dissatisfaction with the product or service available. Two distinct types of information, which the organization may seek, are (1) "preferential" information, which relates the ideal characteristics or attributes for the particular product or service desired by the client, and (2) "directional" information, which relates the desired changes of the characteristics or attributes for the particular product or service in order for that output to come closer to representing an "ideal" output. Directional information does not consist of ideal output but only provides direction for change in the characteristics or attributes of the output.

This research, then, is in line with Douglas' [39] theory of marketing in which it is proposed that the marketing activity should start with the consumer. Based on McGregor's [79] Theory Y concept, Douglas proposes that the consumer be involved in the "planning phases" of production as well as in the setting of criteria for decision making throughout the total enterprise. This is in contrast to the more usual process in which the consumer participated in response to corporate activity through buy-no buy decisions in the marketplace.

With respect to the individual decision maker in an organization, Eichberger [41] relates the importance of both the organization's purpose and its environment, of which the consumer or client is an important component:

> The individual decision maker--particularly the managerial decision maker--plays a central role in this [organization's information/decision making] structure. Yet, without access to an understanding of the organization's purpose and the environment in which the organization exists, he cannot make adjustments in accord with any organizational rationale. Nor can a decision maker function without being "connected" to the appropriate informational channels. The information channels not only serve to keep the decision maker informed, but, just as importantly, provide a means of making things happen [41].

The following discussion considers a few ways in which information from the client can be channeled to the decision maker and a possible analytical description of the process is provided.

Assume that there is one client or client group which can utilize the product or service provided by the organization. The client is assumed to have a total set of needs, wants and desires [58,43] of which some subset could be satisfied by the product or service of the organization. Motives, which are the goals of the buyer impinging upon a buying situation [58] are derived from the biogenic or psychogenic needs, wants, or desires of the consumer that are related to buying and consuming a particular product class [16,82]. Choice criteria [58] are the set of criteria which function to organize and structure a buyer's motives so that the motives that are relevant to the service or product are interrelated and ordered in terms of their importance to the buyer or client. Thus, choice criteria serve the function of permitting goal-directed behavior [58]. In a similar vein, Baker [7] postulated a set of user evaluation criteria, as discussed in Chapter III. It is assumed that the client can specify a desired or ideal level for each choice criterion. Then, information concerning the proposed output of the organization is compared to the established choice criteria by the client before any action, i.e. utilization, purchase, refusal to purchase, is taken. However, this approach disregards any influence of compeition.

It is assumed that the information concerning the proposed output can be in the form of measurable attributes of the production or service. A product or service is viewed as being described by an (r×1) vector $\underset{\sim}{G}_c$. This information is determined by the organization and is sent to the client for evaluation. However, the levels of product or service attributes specified by the organization may be misperceived by the client. That is, the client may view the attribute levels of the output as being different from what the organization believes the true attribute levels are. Leighton [75] states:

> Man acts in terms of what he perceives, and what he perceives must pass not only through his eyes, ears and other special senses to reach his consciousness, but also through the dark iridescent waters of his beliefs [75].

Thus an individual's basic beliefs and the opinions, attitudes, notions, convictions, values, and concepts related to these beliefs, influence the perception of the attribute levels of a product or service.

Of course, perception also plays an important aspect in the central unit—management unit interactions. Goal levels established by the central unit for the administrator of a management unit may be misperceived by the administrator. In a like manner, the degree of internal tension and desirable changes in goal levels specified by an administrator may be misperceived by the central unit.

In addition to perception, there may be an amount of stress generated by the central unit--management unit interactions which may affect decisions made within the organization. The following considerations of stress in an organization are based on the work of Leighton [75].

In an organization, general types of stress particularly disturbing to the emotions and thoughts of an individual are:

1. Persistent frustration of goals, desires, needs, intentions, and plans.

2. Circumstances that promote a dilemna of conflicting and mutually incompatible desires and intentions.

3. Circumstances creating confusion and uncertainty as to what is happening in the present and what can happen in the future.

The following specific types of stress are also seen as disturbing to the emotions and thoughts of an individual in an organization:

1. Loss of means of subsistence, whether in the form of money, jobs, business, or property.

2. Rejection, dislike and ridicule from other people.

3. Capricious and unpredictable behavior on the part of those in authority upon whom one's welfare depends.

Leighton notes that "the prevention of excessive stress is not only an administrative responsibility, but a very practical requirement for effective operation" [75, p.262].

The models in this dissertation are seen as related to stress in that the central unit attempts to reduce the total amount of dissatisfaction or frustration associated with an administrator's inability to achieve goals established by the central unit and also to reduce a client's frustration of not achieving specific need levels. It is recognized that other types of stress may be present and may influence the acts of administrators and clients; however, these factors are not incorporated into the models.

In regard to a consideration of the effects of competition, the concepts of Thibaut and Kelly [102] are used in assuming that the client recognizes not only the product from the organization in question, but also the best available alternative. This assumption is quite common in the marketing and advertising research literature [61,68,78,81]. It may be noted that the best available alternative may consist of "do nothing," (i.e. not purchase any product or not utilize any service, in which case the need or needs are unsatisfied) or a convex combination of several competitive alternatives.

In order to mathematically describe the client's selection, the following variables are defined.

Define α_1 and α_2 as utilization variables which reflect the use of the organization's output and the best available alternative, respectively. That is, α_1 would indicate the client's decision where $\alpha_1 = 0$ indicates no use or purchase of the organization's output, $\alpha_1 = 1$ indicates full use orpurchase of the entire output, and $0 < \alpha_1 < 1$ indicates partial use or purchase of the output. In a like manner α_2 is the utilization variable referring to the purchase or use of the best available alternative.

Two distinct situations, describing two different using or purchasing states, are examined: (1) partial utilization and (2) zero-one utilization. In a partial utilization state, the client is allowed to purchase a portion of the entire output of the organization. It is assumed that the utilization variables are constrained as follows:

$$\alpha_1 + \alpha_2 = 1, \tag{4-29}$$

$$0 \le \alpha_1 \le 1, \tag{4-30}$$

$$0 \le \alpha_2 \le 1. \tag{4-31}$$

Constraint (4-29) implies that the total client utilization be one. Constraints (4-30) and (4-31) allow the utilization of the organization's output and the best available output to vary between no utilization and full utilization. One example of a partial utilization state would occur when a client purchased raw material from more than one supplier. A second example would occur when a client contracts a number of consulting teams, all of whom contribute toward satisfying the overall objectives of the client.

In a zero-one utilization state, the client is allowed only full use or no use of either the organization's output or the best available alternative. It is assumed that the utilization variables are constrained as follows:

$$\alpha_1 + \alpha_2 = 1 \tag{4-29}$$

$$\alpha_1 = 0 \text{ or } 1 \tag{4-32}$$

$$\alpha_2 = 0 \text{ or } 1 \tag{4-33}$$

An example of zero-one utilization state is when a client has a buy-no buy decision.

Partial utilization provides a mechanism for being able, in a mathematical programming sense, to determine the direction of change for each output characteristic. Thus, the model proposed uses "directional" information. In zero-one utilization, "preferential" information is used due to the inherent difficulties of determining direction of change in mixed integer programming model of the overall organizational decision system.

In the next section two models of partial utilization are proposed. The first model considers the goal planning process when an administrator is allowed to deviate from client-oriented goals and several propositions relate the model to observed behavior of organizations. The second model considers the goal planning process when deviations from client-oriented goals are not allowed. In the second section, project redesign is considered, specifically, the attributes of a project are seen as being variable subject to technological constraints. The incorporation of project redesign in the models presented in the previous section is discussed. Zero-one utilization is considered in the third section. The similarities between models used in marketing research and the goal programming model for a buy-no buy situation are described. In the fourth section, the difficulties inherent in a zero-one utilization model are discussed and a model is presented.

Directional Information Models (Partial Utilization)

In the partial utilization situation, the overall problem facing the organizational system is stated as:

Problem I

$$\min \left\{\sum_k (\underline{w}^+_{fk}\underline{d}^+_{fk}+\underline{w}^-_{fk}\underline{d}^-_{fk}+\underline{w}^+_{ak}\underline{d}^+_{ak}+\underline{w}^-_{ak}\underline{d}^-_{ak}+\underline{w}^+_{ck}\underline{d}^+_{ck}+\underline{w}^-_{ck}\underline{d}^-_{ck}) + (\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-)\right\} \quad (4\text{-}34)$$

subject to

$$\left.\begin{aligned} \sum_i \underline{p}^f_{ik}x_{ik} - I\underline{d}^+_{fk} + I\underline{d}^-_{fk} - I\underline{g}^f_k &= \underline{0} \\ \sum_i \underline{p}^a_{ik}x_{ik} - I\underline{d}^+_{ak} + I\underline{d}^-_{ak} &= \underline{g}^a_k \\ \sum_i \underline{p}^c_{ik}x_{ik} - I\underline{d}^+_{ck} + I\underline{d}^-_{ck} - I\underline{g}^c_k &= \underline{0} \\ \sum_i \underline{p}^\ell_{ik}x_{ik} &\le \underline{g}^\ell_k \end{aligned}\right\} k=1,2,\ldots,K \quad (4\text{-}35)$$

$$\sum_k P_k\underline{g}^f_k \ge \underline{G}_f \quad (4\text{-}36)$$

$$\sum_k M_k\underline{g}^c_k - \underline{G}_c = \underline{0} \quad (4\text{-}37)$$

$$\underline{0} \le \underline{g}_k^c \le \underline{b}_k \qquad k=1,2,\ldots,K \tag{4-38}$$

$$\underline{G}_c\alpha_1 + \underline{G}_{alt}\alpha_2 - I\underline{y}^{+} + I\underline{y}^{-} = \underline{n} \tag{4-39}$$

$$\alpha_1 + \alpha_2 = 1 \tag{4-40}$$

$$\underline{y}^{+}, \underline{y}^{-} \ge \underline{0} \tag{4-41}$$

$$\alpha_1, \alpha_2 \ge \underline{0} \tag{4-42}$$

$$\left.\begin{array}{l} \underline{d}_{fk}^{+}, \underline{d}_{fk}^{-} \ge \underline{0} \\ \\ \underline{d}_{ak}^{+}, \underline{d}_{ak}^{-} \ge \underline{0} \\ \\ \underline{d}_{ck}^{+}, \underline{d}_{ck}^{-} \ge \underline{0} \end{array}\right\} \text{ for all } k \tag{4-43}$$

$$x_{ik} \ge 0 \quad \text{for all } i, \quad \text{for all } k \tag{4-44}$$

where

$\underline{G}_c$ is a (r×1) vector characterising the organization's proposed output and is defined by (4-37).

$\underline{b}_k$ is an upper bound on $\underline{g}_k^c$ which is either so large that either it is known to include the optimal solution or any solution exceeding this bound has no realistic interpretation.

$\underline{G}_{alt}$ is a (r×1) vector characterizing the output of the best available alternative and is assumed fixed.

$\underline{n}$ is a (r×1) vector which specifies the ideal levels for the choice criteria.

$\underline{y}^+, \underline{y}^-$ are $(r \times 1)$ vectors of positive and negative deviations, respectively, from the ideal levels $\underline{n}$.

$\underline{v}^+, \underline{v}^-$ are $(1 \times r)$ vectors of weights associated with the positive and negative deviations $\underline{y}^+, \underline{y}^-$, respectively, and are specified by the client.

α_1 is the client utilization variable associated with the organization's proposed output.

α_2 is the client utilization variable associated with the best available alternative.

All other variables, vectors, and matrices are as defined in Problem 0.

The objective function of Problem I is the sum of internal tension (discrepancy dissatisfaction) of the management units plus the weighted dissatisfaction of the alternatives available to the client. Thus the major difference between Problem 0 and Problem I is the inclusion of the client's weighted dissatisfaction.

It will be shown that Benders' Partitioning Procedure can be used to solve Problem I and the behavioral appeal of this approach will be discussed.

Again let $\underline{Y}_k$, $\underline{W}_k$, $_k$, F_k, A_k, C_k, and L_k for $k=1,2,\ldots,K$ be defined as in Problem 0. Let the set of $(\underline{g}_k^f, \underline{g}_k^c)$ be defined by

$$S(I) = \{(\underline{g}_k^f, \underline{g}_k^c) : \sum_k P_k \underline{g}_k^f \geq \underline{G}_f; \quad 0 \leq \underline{g}_k^c \leq \underline{b}_k, \quad k=1,2,\ldots,K\}$$

Problem I can then be rewritten as

Problem I-1

$$\min \{\sum_k z_k(\underline{g}_k^f,\underline{g}_k^c) + (\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-)\} = \{\sum_k \underline{W}_k\underline{Y}_k + (\underline{v}^+\underline{y}^+ - \underline{v}^-\underline{y}^-)\} \qquad (4\text{-}45)$$

subject to

$$\begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k - \begin{bmatrix} I\underline{g}_k^f \\ 0 \\ I\underline{g}_k^c \\ 0 \end{bmatrix} \begin{cases} = \underline{0} \\ = \underline{g}_k^a \\ = \underline{0} \\ \geq -\underline{g}_k^\ell \end{cases}, \quad k=1,2,\ldots,K \qquad (4\text{-}46)$$

$$\sum_k M_k\underline{g}_k^c - \underline{G}_c = \underline{0} \qquad (4\text{-}37)$$

$$\underline{G}_c\alpha_1 + \underline{G}_{alt}\alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n} \qquad (4\text{-}39)$$

$$\alpha_1 + \alpha_2 = 1 \qquad (4\text{-}40)$$

$$\underline{y}^+, \quad \underline{y}^- \geq \underline{0} \qquad (4\text{-}41)$$

$$\alpha_1, \quad \alpha_2 \geq 0 \qquad (4\text{-}42)$$

$$\underline{Y}_k \geq \underline{0}, \quad k=1,2,\ldots,K \qquad (4\text{-}47)$$

$$(\underline{g}_k^f,\underline{g}_k^c) \in S(I) \qquad (4\text{-}48)$$

For a fixed $(\underline{g}_k^f,\underline{g}_k^c) = (\underline{g}_k^{ft},\underline{g}_k^{ct}) \in S(I)$, the problem becomes

Problem I^t

$$\min \{\sum_k \underline{W}_k \underline{Y}_k + (\underline{v}^+ \underline{y}^+ + \underline{v}^- \underline{y}^-)\} \tag{4-45}$$

subject to

$$\begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^{ft} \\ = \underline{g}_k^{a} \\ = \underline{g}_k^{ct} \\ \geq -\underline{g}_k^{\ell} \end{cases}, \quad k=1,2,\ldots,K \tag{4-49}$$

$$\sum_k M_k \underline{g}_k^{ct} = \underline{G}_c^t \tag{4-50}$$

$$\underline{G}_c^t \alpha_1 + \underline{G}_{alt} \alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n} \tag{4-51}$$

$$\alpha_1 + \alpha_2 = 1 \tag{4-40}$$

$$\underline{y}^+, \ \underline{y}^- \geq \underline{0} \tag{4-41}$$

$$\alpha_1, \ \alpha_2 \geq 0 \tag{4-42}$$

$$\underline{Y}_k \geq \underline{0}, \quad k=1,2,\ldots,K \tag{4-47}$$

However, with $(\underline{g}_k^f, \underline{g}_k^c)$ fixed, Problem I^t is separable into K + 1 problems. There are K problems of the form:

Problem A_k^t for each k=1,2,...,K

$$\min z_k(\underline{g}_k^{ft},\underline{g}_k^{ct}) = \underline{W}_k\underline{Y}_k \qquad (4\text{-}52)$$

$$\text{subject to} \quad \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^{ft} \\ = \underline{g}_k^{a} \\ = \underline{g}_k^{ct} \\ \geq \underline{g}_k^{\ell} \end{cases} \qquad (4\text{-}53)$$

$$\underline{Y}_k \geq \underline{0} \qquad (4\text{-}54)$$

And there is one problem of the form:

Problem C^t

$$\min V(\underline{G}_c^t) = (\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-) \qquad (4\text{-}55)$$

$$\text{subject to} \quad \underline{G}_c^t\alpha_1 + \underline{G}_{alt}\alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n} \qquad (4\text{-}51)$$

$$\alpha_1 + \alpha_2 = 1 \qquad (4\text{-}40)$$

$$\underline{y}^+, \quad \underline{y}^- \geq \underline{0} \qquad (4\text{-}41)$$

$$\alpha_1, \quad \alpha_2 \geq 0 \qquad (4\text{-}42)$$

Using (4-40), let $\alpha_1 = 1 - \alpha_2$, then Problem C^t can be written as:

Problem C^t - 1

$$\min \quad V(\underline{G}_c^t) = (\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-) \tag{4-55}$$

$$\text{subject to} \quad (G_{alt} - \underline{G}_c^t)\alpha_2 - I\underline{y}^+ + I\underline{y}^- = (\underline{n} - \underline{G}_c^t) \tag{4-56}$$

$$\alpha_2 \leq 1 \tag{4-57}$$

$$\underline{y}^+, \quad \underline{y}^- \geq \underline{0} \tag{4-41}$$

$$\alpha_2 \geq 0 \tag{4-58}$$

Let $\pi_k = (\underline{\pi}_k^f, \underline{\pi}_k^a, \underline{\pi}_k^c, \underline{\pi}_k^\ell)$ be a $\left(1\times(f+a_k+c+\ell_k)\right)$ vector of dual variables for Problem A_k^t and $(\underline{\beta},\mu)$ be a $\left((r+1)\times 1\right)$ vector of dual variables for Problem C^t - 1.

The dual of Problem A_k^t can be written as:

Dual D_k^t

$$\max \{\phi(g_k^{ft}, g_k^{ct}): \pi_k \epsilon U_k\} = \{\underline{\pi}_k^f \underline{g}_k^{ft} + \underline{\pi}_k^a \underline{g}_k^a + \underline{\pi}_k^c \underline{g}_k^{ct} - \underline{\pi}_k^\ell \underline{g}_k^\ell : \pi_k \epsilon U_k\} \tag{4-59}$$

where

$$U_k = \left\{ \underline{\pi}_k : \underline{\pi}_k \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \leq \underline{W}_k, \quad \underline{\pi}_k^\ell \geq \underline{0} \right\} \tag{4-60}$$

The dual of Problem $C^t - 1$ can be written as

Dual $C^t - 1$

$$\max \{\underline{\beta}(\underline{n}-\underline{G}_c^t) + \mu : (\underline{\beta},\mu)\epsilon B\} \qquad (4\text{-}61)$$

where

$$B = \{(\underline{\beta},\mu): \underline{\beta}(\underline{G}_{alt}-\underline{G}_c^t) + \mu \le 0, -v^+ \le \underline{\beta} \le \underline{v}^-, \mu \ge 0\}$$

In order to remove extreme rays from consideration, the following assumption is made:

Assumption 4-2. Assume that a feasible solution exists to Dual D_k^t and Dual $C^t - 1$, the constraint set of Dual D_k^t is strictly bounded, and the constraint set of Dual $C^t - 1$ is strictly bounded. Then the maximum value of Dual D_k^t occurs at an extreme point of the constraint set of Dual D_k^t and the maximum value of Dual $C^t - 1$ occurs at an extreme point of the constraint set of Dual $C^t - 1$ and no extreme rays would exist for Dual D_k^t or for Dual $C^t - 1$.

Problem I can then be expressed as:

$$\min_{(\underline{g}_k^f,\underline{g}_k^c)\in R_1} \left[\sum_k \min\left[\underline{W}_k\underline{Y}_k : \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^f \\ = \underline{g}_k^a \\ = \underline{g}_k^c \\ \geq -\underline{g}_k^\ell \end{cases}, \quad \underline{Y}_k \geq 0 \right] + \min\left[\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^- : \right.\right.$$

$$\left.\left. (\underline{G}_{alt} - \sum_k M_k\underline{g}_k^c)\alpha_2 - I\underline{y}^+ + I\underline{y}^- = (\underline{n} - \sum M_k\underline{g}_k^c),\ \alpha_2 \leq 1,\ \alpha_2 \geq 0 \right] \right]$$

$$= \min_{(\underline{g}_k^f,\underline{g}_k^c)\in R_1} \left[\sum_k \max\left[\underline{\pi}_k^f\underline{g}_k^f + \underline{\pi}_k^a\underline{g}_k^a + \underline{\pi}_k^c\underline{g}_k^c - \pi_k^\ell\underline{g}_k^\ell : \underline{\pi}_k \in U_k \right] + \right.$$

$$\left. \max\left[\underline{\beta}(\underline{n} - \sum_k M_k\underline{g}_k^c) + \mu : (\underline{\beta},\mu)\in B \right] \right]$$

where

$$R_1 = \{(\underline{g}_k^f,\underline{g}_k^c)\in S(I): \exists \text{ a feasible } \underline{Y}_k,\quad k=1,2,\ldots,K \text{ and}$$

$$\exists \text{ a feasible } \alpha_2 \text{ for Problem I}\}$$

$$= \{(\underline{g}_k^f,\underline{g}_k^c)\in S(I): \quad \text{For each } \pi_k \in U_k \quad k=1,2,\ldots,K$$

$$\max(\pi_k^f\underline{g}_k^f + \pi_k^a\underline{g}_k^a + \pi_k^c\underline{g}_k^c - \pi_k^\ell\underline{g}_k^\ell < \infty \text{ and for each}$$

$$(\underline{\beta},\mu) \in B,\ \max\left(\underline{\beta}(\underline{n} - \sum_k M_k\underline{g}_k^c) + \mu\right) < \infty\}$$

Then Problem I can be further expressed as

Problem I-2

$$\min \sum_k \sigma_k + \gamma \tag{4-62}$$

subject to
$$\sigma_k \geq \min_{\underline{\pi}_k \in U_k} [\pi_k^f \underline{g}_k^f + \pi_k^a \underline{g}_k^a + \pi_k^c \underline{g}_k^c - \pi_k^\ell \underline{g}_k^\ell] \tag{4-63}$$

for $k=1,2,\ldots,K$

$$\gamma \geq \max_{(\underline{\beta},\mu)\in B} [\underline{\beta}(\underline{n} - \sum_k M_k \underline{g}_k^c) + \mu] \tag{4-64}$$

$$(\underline{g}_k^f, \underline{g}_k^c) \in R_1 \tag{4-65}$$

Due to Assumption 2, only extreme points need be considered. Let $\underline{\pi}_k^{S_k}$, $S_k=1,2,\ldots,E_k$ be the extreme points for Dual D_k^t for $k=1,2,\ldots,K$ and let $(\underline{\beta}^\tau, \mu^\tau)$, $\tau=1,2,\ldots,T$ be the extreme point of Dual $C^t - 1$. The Problem I-2 can be expressed as

Problem I-3

$$\min \sum_k \sigma_k + \gamma \tag{4-62}$$

subject to
$$\sigma_k \geq \pi_k^{fS_k} \underline{g}_k^f + \pi_k^{aS_k} \underline{g}_k^a + \pi_k^{cS_k} \underline{g}_k^c - \pi_k^{\ell S_k} \underline{g}_k^\ell \tag{4-66}$$

for $S_k=1,2,\ldots,E_k$

and $k=1,2,\ldots,K$

$$\gamma \geq \underline{\beta}^{\tau}(\underline{n} - \sum_{k} M_k \underline{g}_k^c) + \mu^{\tau} \qquad (4\text{-}67)$$

$$\text{for } \tau = 1,2,\ldots,T$$

$$\sum P_k \underline{g}_k^f \geq \underline{G}_f \quad \text{and} \quad 0 \leq \underline{g}_k^c \leq \underline{b}_k \text{ for all } k \qquad (4\text{-}68)$$

Proof of finiteness is given by Benders [18] and Lasdon [68] when S(I) is closed and bounded. The rows of Problem I-3 can be generated as and when required.

Given Assumption 2, the solution procedure for solving Problem I would be as follows:

Step 1. The central unit arbitrarily selects goal levels $\underline{g}_k^f = \underline{g}_k^{f1} < \infty$ and $\underline{g}_k^c = \underline{g}_k^{c1} < \infty$ for k=1,2,...,K such that $\sum_k P_k \underline{g}_k^{f1} \geq \underline{G}_f$ and $0 \leq \underline{g}_k^{c1} \leq \underline{b}_k$ for all k. Initially set $\sigma_k = -\infty$ for k=1,2,...,K and $\gamma = -\infty$. There are no constraints of the form (4-66) or (4-67) present. The $(\underline{g}_k^{f1}, \underline{g}_k^{c1})$ for k=1,2,...,K is sent to the respective management unit and $(\sum_k M_k \underline{g}_k^{c1})$ to the client.

Step 2. Each management unit receives $(\underline{g}_k^{f1}, \underline{g}_k^{c1})$ from the central unit and solves Problem A_k^1 and determines the optimal value of the objective function $z_k(\underline{g}_k^{f1}, \underline{g}_k^{c1})$ and $\underline{\pi}_k^{f1}$, $\underline{\pi}_k^{c1}$. This information is sent to the central unit. The client solves Problem C^1 - 1 and finds the optimal value of the objective function $V^*(\underline{G}_c^1)$ and $(\underline{\beta}^1)$. This information is sent to the central unit. Due to Assumption 2, the values of the objective functions of Dual D_k^1 and Dual C^1 - 1 are finite and equal to the values of the objective functions of Problem A_k^1 and Problem

C-1, respectively. Therefore, the value of the objective function of Problem A_k^1 is finite and $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1}) > -\infty$ and the value of the objective function of Problem C^1 - 1 is finite and $V^*(\underline{G}_c^t) > -\infty$.

Step 3. Since $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1}) > \sigma_k = -\infty$ for all k and $V^*(\underline{G}_c^1) > \gamma = -\infty$ the central unit adds one constraint for each management unit of the form (4-66) and one constraint for the client of the form (4-67) and the problem becomes

<u>Problem I-4.</u> $\min \{\sum_k \sigma_k + \gamma\}$ (4-62)

subject to

$$\sigma_k \geq z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1}) - \pi_k^{f1}\underline{g}_k^{f1} - \pi_k^{c1}\underline{g}_k^{c1} + \pi_k^{f1}\underline{g}_k^{f} + \pi_k^{c1}\underline{g}_k^{c} \tag{4-69}$$

for k=1,2,...,K

$$\gamma \geq V_k^*(\underline{G}_c^1) + \underline{\beta}^1(\sum_k M_k\underline{g}_k^{c1}) - \underline{\beta}^1(\sum M_k\underline{g}_k^{c}) \tag{4-70}$$

$$\sum P_k\underline{g}_k^f \geq \underline{G}_f \quad \text{and} \quad 0 \leq \underline{g}_k^f \leq \underline{b}_k \text{ for all k} \tag{4-68}$$

The solution of this problem yields σ_k^2 and $(\underline{g}_k^{f2},\underline{g}_k^{c2})$ k=1,2,...,K and $\underline{G}_c^2 = \sum_k M_k\underline{g}_k^{c2}$. $(\underline{g}_k^{f2},\underline{g}_k^{c2})$ are sent to management unit k and $\underline{G}_c^2$ is sent to the client.

At Iteration T-1

Step 4. The central unit solves Problem I-4 with at most T - 1 constraints of the form (4-69) for each management unit and at most T - 1 constraints of the form (4-70) for the client. The resulting optimal values are σ_k^T, $(\underline{g}_k^{fT},\underline{g}_k^{cT})$, γ^T and $\underline{G}_c^T = \sum M_k\underline{g}_k^{cT}$. $(\underline{g}_k^{f1},\underline{g}_k^{c1})$ are sent to the respectivemanagement unit and $\underline{G}_c^T = \sum M_k \underline{g}_k^{cT}$ is sent to the client.

Step 5. The management unit solves Problem A_k^T and the values $Z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT})$, $\underline{\pi}_k^{fT}$, and $\underline{\pi}_k^{cT}$ are sent to the central unit. The client solves Problem $C^T - 1$ and sends $V^*(\underline{G}_c^T)$ and $\underline{\beta}^T$ to the central unit.

Step 6. The central unit checks to determine if any $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT}) > \sigma_k^T$ for k=1,2,...,K or $V^*(\underline{G}_c^T) > \gamma^T$. If an inequality exists, then a constraint of the form (4-69) or (4-70) is added and return to Step 4. If $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT}) \leq \sigma_k^T$ for all k and $V^*(\underline{G}_c^T) \leq \gamma^T$, then stop. An optimal solution has been found for Problem 1.

The information flow in the organizational system depicted in the above steps may be considered as follows. The central unit initially selects the central unit oriented and client-oriented goals. Although it is stated that these goals may be arbitrarily selected, the central unit may have additional information which aids in the selection of "good" starting points. The goals are sent to the respective management units and the client-oriented goals are combined to determine the proposed organizational output.

Each management unit selects the activity levels for each project in order to minimize the sum of weighted deviations from central unit oriented goals, management unit goals and client-oriented goals. Each management unit would then send information related to the minimum internal tension and to the desired direction of change (with dual variables) for central unit oriented and client-oriented goals.

Using the proposed organizational output and the best available alternative, the client determines the utilization which minimizes his weighted dissatisfaction. Information, which conveys the client's dissatisfaction and the direction of change of the proposed organizational output, is sent to the central unit.

Given the information from the management units and client, the central unit attempts to re-establish central unit-oriented goals and client-oriented goals in order to minimize the sum of internal tension and client dissatisfaction.

If the $(\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-)$ component of the objective function of Problem I is considered as a measure of organizational inflexibility, then the total objective of Problem I may be considered as minimizing the sum of internal tension and inflexibility. The term inflexibility is used since a large value of $(\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-)$ at the start of the interaction and a reduced value at the end of interaction gives a measure of how flexible the organization is being in responsive to a client.

In Problem I, the central unit might find it desirable to give priority to either internal tension or flexibility. In Problem I, the central unit has no direct control over the weights given to deviations from goals for the management units or over weights given to the deviations from the ideal values for the client. Let Q_1 and Q_2 be trade-off weights, determined by the central unit, between internal tension and inflexibility, then the central unit would solve Problem 5 instead of Problem I-4 at iteration T-1.

Problem I-5

$$\min \{Q_1(\sum_k \sigma_k) + Q_2\gamma\} \tag{4-71}$$

subject to $$\alpha_k \geq z_k^*(g_k^{ft}, g_k^{ct}) - \underline{\pi}_k^{ft} \underline{g}_k^{ft} - \underline{\pi}_k^{ct} \underline{g}_k^{ct} + \underline{\pi}_k^{ft} \underline{g}_k^{f} + \underline{\pi}_k^{ct} \underline{g}_k^{c} \tag{4-72}$$

for $t=1,2,\ldots,T-1$

$k=1,2,\ldots,K$

$$\gamma \geq V_k^*(\underline{G}_c^t) + \underline{\beta}^t(\sum M_k \underline{g}_k^{ct}) - \underline{\beta}^t(\sum M_k \underline{g}_k^{c}) \tag{4-73}$$

for $t=1,2,\ldots,T-1$

$$\sum_k P_k \underline{g}_k^f \geq \underline{G}_k \quad \text{and} \quad 0 \leq \underline{g}_k^f \leq \underline{b}_k \text{ for all } k \tag{4-74}$$

Step 5 and Step 6 are the same as for Problem I without the trade-off weights.

If $Q_1 <<< Q_2$, then the central unit would be placing a high emphasis upon client satisfaction and a small emphasis upon the administrator's dissatisfaction with client-oriented goals. On the other hand, $Q_1 >>> Q_2$ would imply a greater emphasis given to internal tension than to client satisfaction.

It should be noted that at the last iteration, say iteration T, $\underline{g}_k^{cT}$, $k=1,2,\ldots,K$ are the final client-oriented goal levels; however, x_{ik}^T, for all i, for all k, are the actual activity levels and $\sum_i \underline{p}_{ik}^c x_{ik}^T$ would be the actual contribution toward goal $\underline{g}_k^{cT}$. If the actual outputs from the management units are sent to the client after the final iteration, then the client would be evaluating $\sum_k M_k(\sum_i \underline{p}_{ik}^c x_{ik}^T)$ instead of $\sum_k M_k \underline{g}_k^{cT}$. This leads to the following observation.

Observation. Even if the central unit is able to establish client-oriented goals which decrease the amount of client dissatisfaction, the actual outputs from the management units may not result in the same decrease in client dissatisfaction.

There exist at least two explanations for the actual output not decreasing client dissatisfaction as much as the goal guidelines: (1) the goal guidelines may suggest activity levels which do not satisfy the exogenous inequality constraints, or (2) the administrator assigns low priorities to client-oriented goals and high priorities are assigned to funder or administrator-oriented goals. In the former instance, one would expect the administrator to indicate the infeasibility of meeting the client-oriented goals. In the latter instance, the administrator may emphasize any conflicts which exist in attaining both funder-oriented and client-oriented goals.

In addition, the central unit may emphasize internal tension of the organization by choosing a Q_1 much larger than Q_2 in Problem I-5. If this occurs and if the management units place a low priorities (small values of $\underline{w}_{ck}^+, \underline{w}_{ck}^-$) upon the deviations from client-oriented goals relative to the priorities upon deviations from central unit oriented goals or management unit goals, then the client has little or no impact upon both the proposed output or actual output. On the other hand, if the central unit places a high priority upon the client-oriented goals and the management units do likewise, then the client has a large impact upon the organization's decisions. These comments suggest the following two observations:

Observation. If central unit emphasizes the minimization of internal tension and/or administrators place a low priority upon achieving client-oriented goals, then improved client-oriented output would occur only if it was a by-product of achieving central unit and/or administrator-oriented goals.

Observation. If the central unit emphasizes the flexibility of the organization to respond to client dissatisfaction and administrators place high priorities upon client-oriented goals, then the organization appears to act as though it were controlled by the client.

With respect to the first proposition, an extreme form of behavior of professionals in service organizations, which has been observed, is that administrators lose sight of the interests of their users or clients [62,28]. This loss of interest was due to the administrators' concern with their own status or career or through preoccupation with administrative problems. This is reflected in the model, in the former instance, when an administrator overemphasizes, i.e. place a high weight, upon deviations from his established goals, and in the latter instance, when the funder has a main concern of minimizing his administrators' dissatisfaction or an administrator attempts to achieve funder-oriented objectives without concern for client-oriented objectives. The end result in the real life situation is that the organization ceases to be responsive to user needs. The same end result would also be reflected by the model.

With respect to the second proposition, the other extreme form of behavior observed in service organizations is that administrators become captives of their users and essentially surrender to them the power to determine the nature of the service furnished [62,28]. This form of behavior would be illustrated by the indirect client influence model when the funder establishes a high priority to increasing client utilization and the administrators place a high priority upon client-oriented goals relative to funder-oriented or their own goals. In this situation both the funder and administrator become extremely sensitive to feedback from the client in order to improve the output as viewed by the client with almost complete disregard for their own goals. The organization is seen as being over-responsible to the user, which may mean, in a service organization, that the professional no longer uses his skills and training in determining an improved service for the client.

It is important to recognize that the indirect client influence model not only can reflect the end results which have been observed in organizations, but also appears consistent with the process by which the results are obtained.

Since there may exist a difference between the client-oriented goals and the actual output at the last iteration, the central unit may attempt to give a guarantee that the proposed output and the actual output will be identical. This may be accomplished in the overall organization system problem by not allowing the management units to deviate from the client-oriented goals. The problem may be written as

Problem II

$$\min \{\sum_k (\underline{w}^+_{fk}\underline{d}^+_{fk}+\underline{w}^-_{fk}\underline{d}^-_{fk}+\underline{w}^+_{ak}\underline{d}^+_{ak}+\underline{w}^-_{ak}\underline{d}^-_{ak}) + (\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-)\} \tag{4-75}$$

$$\left.\begin{array}{l} \sum_i p^f_{ik}x_{ik} - Id^+_{fk} + Id^-_{fk} - I\underline{g}^f_k = \underline{0} \\ \sum_i \underline{p}^a_{ik}x_{ik} - I\underline{d}^+_{ak} + I\underline{d}^-_{ak} = \underline{g}^a_k \\ \sum_i \underline{p}^c_{ik}x_{ik} - I\underline{g}^c_k = \underline{0} \\ \sum_i \underline{p}^\ell_{ik}x_{ik} \le \underline{g}^\ell_k \end{array}\right\} k=1,2,\ldots,K \tag{4-76}$$

$$\sum P_k\underline{g}^f_k \ge \underline{G}_f \tag{4-77}$$

$$0 \le \underline{g}^c_k \le \underline{b}_k \text{ for all } k \tag{4-78}$$

$$\sum_k M_k\underline{g}^c_k - I\underline{G}_c = \underline{0} \tag{4-79}$$

$$\underline{G}_c\alpha_1 + \underline{G}_{alt}\alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n} \tag{4-80}$$

$$\alpha_1 + \alpha_2 = \underline{n} \tag{4-81}$$

$$\underline{d}_{fk}^{+}\ \underline{d}_{fk}^{-} \geq \underline{0} \quad \text{for all } k \tag{4-82}$$

$$\underline{d}_{ak}^{+},\underline{d}_{ak}^{-} \geq \underline{0} \quad \text{for all } k \tag{4-83}$$

$$x_{ik} \geq 0 \quad \text{for all } i, \text{ for all } k \tag{4-84}$$

$$\underline{y}^{+},\underline{y}^{-} \geq \underline{0} \tag{4-86}$$

$$\alpha_1,\alpha_2 \geq 0 \tag{4-86}$$

The development of a solution procedure would be similar to the procedure developed for Problem I and will not be repeated. A few comments are in order, however. First of all, if there exists a feasible solution to Problem II, then the output expected by the client at the final iteration $\underline{G}_c^T$ is received by the client since no deviations from client-oriented goals are allowed. Secondly, since the central unit is establishing the goals without specific information from the management units regarding the project attributes, a problem of feasibility might easily arise.

In the next section, the possibility of project redesign is considered.

Project Redesign

Consider the partial utilization situation in which the problem facing the organizational system can be described by Problem I.

In problem I, the project attribute vectors $\underline{p}_{ik} = \begin{pmatrix} \underline{p}^f_{ik} \\ \underline{p}^a_{ik} \\ \underline{p}^c_{ik} \\ -\underline{p}^\ell_{ik} \end{pmatrix}$ were assumed fixed. It is now assumed that the project vectors are selected from a convex set which may be defined by the technological constraints related to a specific project area. Thus a partial utilization situation with the allowance of project redesign may be stated as:

<u>Problem I-RD</u> which is defined as Problem I with $\underline{p}_{ik} \in J_{ik}$, where J_{ik} is a convex set. For simplicity, it can be assumed that the set J_{ik} is defined as

$$J_{ik} = \{\underline{p}_{ik}\colon A_{ik}\underline{p}_{ik} \le \underline{C}_{ik}\} \quad \text{for all } i, \text{ for all } k$$

where

A_{ik} is a $\left(m\times(f+a_k+c+\ell_k)\right)$ matrix, whose rows determine the linear combination of project attributes which are restricted by m technological limits.

$\underline{C}$ is an $(m\times 1)$ vector of technological limits.

Dantzig [33] refers to this type of problem, in which there are variable project attribute vectors, as a generalized linear programming problem.

Since the same basic partitioning scheme may be used with Problem I-RD as was used with Problem I, it is not repeated here. However, the solution procedure is modified and will be described. The solution procedure for solving Problem I-RD is as follows:

Step 1. The central unit arbitrarily selects goal levels $\underline{g}_k^f = \underline{g}_k^{f1} < \infty$ and $\underline{g}_k^c = \underline{g}_k^{c1} < \infty$ for $k = 1,2,\ldots,K$ such that $\sum_k P_k \underline{g}_k^{f1} \geq \underline{G}_f$ and $0 \leq \underline{g}_k^{c1} \leq \underline{b}_k$ for all k. Initially set $\sigma_k = -\infty$ for $k=1,2,\ldots,k$ and $\gamma = -\infty$. There are no constraints of the form (4-66) or (4-67) present. The $(\underline{g}_k^{f1},\underline{g}_k^{c1})$ for $k=1,2,\ldots,K$ is sent to the respective management unit and $(\sum_k M_k \underline{g}_k^{c1})$ is sent to the client.

Step 2. Each management unit receives $(\underline{g}_k^{f1},\underline{g}_k^{c1})$ from the central unit and selects an arbitrary $\underline{p}_{ik}' \in J_{ik}$ for $i=1,2,\ldots,n_k$. Using the p_{ik}' and $(\underline{g}_k^{f1},\underline{g}_k^{c1})$ the management unit solves Problem A_k^1 or Dual D_k^1 and determines the optimal value of the objective function $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1})$ and $(\underline{\pi}_k^{f1},\underline{\pi}_k^{a1},\underline{\pi}_k^{c1},\underline{\pi}_k^{\ell 1})$. Then, the management unit would send $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1})$ $\underline{\pi}_k^{f1}$, $\underline{\pi}_k^{c1}$ to the central unit. The client solves Problem $C^t - 1$ and finds the optimal value of the objective function $V^*(\underline{G}_c^1)$ and $\underline{\beta}^1$. This information is sent to the central unit. Using Assumption 2, $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1})$ and $V^*(\underline{G}_c')$ are finite.

Step 3. Project redesign--a new project would be more desirable, i.e. considered for acceptance, if the simplex optimality criterion were not satisfied which occurs if $\min(-\underline{\pi}_k^1 \underline{p}_{ik}) < 0$. Thus it would be desirable to minimize $(-\pi_k^1 \underline{p}_{ik}) = (\pi_k^{f1} \underline{p}_{ik}^f + \underline{\pi}_k^{a1} \underline{p}_{ix}^a + \underline{\pi}_k^{c1} \underline{p}_{ik}^c - \underline{\pi}_k^{\ell 1} \underline{p}_{ik}^{\ell})$. Thus the administrator would solve the following redesign problem for each project $i=1,2,\ldots,n_k$ which can be considered for redesign.

Problem RD_{ik}^{t}—

$$\min \quad -\pi_k^t \underline{p}_{ik}$$

$$\text{subject to} \quad A_{ik}\underline{p}_{ik} \le \underline{\xi}_{ik}$$

The optimal solution, $\underline{p}_{ik}^{(t)}$ would be added as an additional column to Problem A_k^t, if $-\underline{\pi}_k^t \underline{p}_{ir}^{(t)} < 0$. If $(-\underline{\pi}_k^t \underline{p}_{ik}^{(t)}) \ge 0$, then the redesigned project would not need to be considered for entrance into an administrator's set of projects since it would not be advantageous for the purpose of minimizing the value of the management unit's objective function.

Step 4. Since $z_k^*(\underline{g}_k^{f1}, \underline{g}_k^{c1}) > \sigma_k = -\infty$ for all k and $V^*(\underline{G}_c^1) > \gamma = -\infty$, the central unit adds one constraint for each management unit of the form (4-66) and one constraint for the client of the form (4-67) and Problem I-4 is solved. The solution yields σ_k^2 and $(\underline{g}_k^{f2}, \underline{g}_k^{c2})$, k=1,2,..., K and $\underline{G}_c^2 = \sum M_k \underline{g}_k^2$. $\underline{G}_c^2$ is sent to the client and $(\underline{g}_k^{f2}, \underline{g}_k^{c2})$ are sent to the management unit.

At iteration T-1

Step 5. The central unit solves Problem I-4 with at most T-1 constraints of the form (4-69) for each management unit and at most T-1 constraints of the form (4-70) for the client. The resulting optimal values are σ_k^T, $(\underline{g}_k^{fT}, \underline{g}_k^{cT})$, γ^T, and $\underline{G}_c^T = \sum M_k \underline{g}^{cT}$. $(\underline{g}_k^{fT}, \underline{g}_k^{cT})$ are sent to the respective management unit and $\underline{G}_c^T$ is sent to the client.

Step 6. The management unit solves Problem A_k^T and the values $z_k^*(\underline{g}_k^{fT},\underline{g}_k^{cT})$, $\underline{\pi}_k^{fT}$ and $\underline{\pi}_k^{cT}$ are sent to the central unit. $\underline{\pi}_k^T$ is used with project i of management unit k for possible project redesign. The client solves Problem C^T-1 and sends $V^*(\underline{G}_c^T)$ and $\underline{\beta}^T$ to the central unit.

Step 7. The central unit checks to determine if any $z_k^*(\underline{g}_k^{fT},\underline{g}_k^{cT}) > \sigma_k^T$ for k=1,2,...,K or $V^*(\underline{G}_c^T) > \gamma^T$. If an inequality exists, then a constraint of the form (4-69) or (4-70) is added and return to Step 5.

The management unit solves Problem RD_{ik}^T using $\underline{\pi}_k^T$. If any one new redesign, $i=1,2,\ldots,n_k$, $\underline{p}_{ik}^{(T)}$ is such that $\underline{\pi}_k^T\underline{p}_{ik}^{(T)} > 0$, then added the project and return to Step 6.

If $z_k^*(\underline{g}_k^{fT},\underline{g}_k^{cT}) \le \sigma_k^T$ for all k, $V^*(\underline{G}_c^T) \le \gamma^T$, and $\underline{\pi}_k^T\underline{p}_{ik}^{(T)} \le 0$ for all i and all k, then stop. An optimal solution has been found for Problem I-RD.

To determine the final project attributes for project i of management unit k, let $\underline{p}_{ik}^{(1)},\underline{p}_{ik}^{(2)},\ldots,\underline{p}_{ik}^{(T)}$ be the arbitrary and redesigned projects introduced and $x_{ik}^{(1)},x_{ik}^{(2)},\ldots,x_{ik}^{(T)}$ be the final activity levels associated with the arbitrary and redesigned projects. Any solution to Problem I-RD with projects added can be rewritten back in the original form of Problem I-RD by setting $x_{ik} = x_{ik}^{(1)} + x_{ik}^{(2)} + \ldots + x_{ik}^{(T)}$ and letting the coefficients of x_{ik} be given by

$$\underline{p}_{ik} = \underline{p}_{ik}^{(1)}\left(\frac{x_{ik}^{(1)}}{x_{ik}}\right) + \underline{p}_{ik}^{(2)}\left(\frac{x_{ik}^{(2)}}{x_{ik}}\right) + \ldots + \underline{p}_{ik}^{(T)}\left(\frac{x_{ik}^{(T)}}{x_{ik}}\right)$$

$$\text{for } (x_{ik}^{(1)}+x_{ik}^{(2)}+\ldots+x_{ik}^{(T)}) > 0.$$

The right-hand side is clearly a convex combination of T points lying in a convex set defined by J_{ik}; as a consequence the point $\underline{p}_{ik}$ must lie in this convex set also.

Dantzig [32, Ch.22] shows that the solution procedure is finite and if any project added to Problem A_k is not active, it may be dropped from the current set of projects because it is included in the convex set J_{ik} defining the redesigned projects. Therefore, if a project is redesigned by solving Problem RD_{ik}^{t} and the resulting project has characteristics which satisfy the acceptance criterion (i.e. $-\underline{\pi}_k^t \underline{p}_{ik}^{(t)} < 0$), then the inclusion of the project in the current set of alternatives should decrease an administrator's internal tension.

Although project redesign was considered with Problem I, there is no addition difficulty of allowing project redesign, $\underline{p}_{ik} \in J_{ik}$, for all i, for all k in Problem II.

In addition, there would be no difficulty in not attempting a project redesign at each iteration. Since an administrator may be viewed as attempting to minimize deviations without going through the additional step of project redesign, there is no difficulty in redesigning after central unit-management unit interaction has terminated given an initial set of projects. Essentially, the management unit would arbitrarily select a set of projects, and interaction with the central unit would occur as specified in the steps for solving Problem I. Since at optimality for Problem I, there may exist $z_k^*(\underline{g}_k^{fT},\underline{g}_k^{cT}) > 0$, the $k\mathit{th}$ management unit may seek to decrease $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT})$ be redesigning one or more projects using the optimal $\underline{\pi}_k^T$. If project ik may be redesigned so that $-\underline{\pi}_k^T \underline{p}_{ik}^1 < 0$ and $\underline{p}_{ik}^1 \in J_{ik}$, then Problem A_k^T may be resolved with an additional project column specifying the redesigned project $\underline{p}_{ik}^1$. Since $-\underline{\pi}_k^T p_{ik}^1 < 0$, project ik^1 is eligible to be activated and the resulting optimal value $z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT})^1 \leq z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT})$. In addition, the optimal dual values $\underline{\pi}_k^{fT'}$, $\underline{\pi}_k^{cT'}$ may be used to renew interaction with the central unit.

Attitude Measurement and Goal Programming

Much of literature in the marketing and advertising areas is aimed at determining and measuring a consumer's attitude toward a particular brand. Although many definitions of attitude have been given, Allport [2] provides an encompassing definition which can be stated as: "An attitude is a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related [2, p.8]. Although an attitude is seen as a "state of readiness," Allport goes on to mention that "an attitude characteristically provokes behavior that is acquisitive or avertive, faborable or unfavorable, affirmative or negative toward the object or class of objects with which it is related" [2, p.8]. Thus an attitude is believed to lead to some type of response.

In attempting to measure attitude, Fishbein [43] proposes a model in which an individual's attitude toward any object is considered as a function of (1) the strength of his beliefs about the object and (2) the evaluative aspects of those beliefs. A simple additive model of the form is given as

$$A_0 = \sum_{j=1}^{N} B_j a_j \qquad (4\text{-}50)$$

where A_0 is the attitude toward object 0, B_j is the strength of belief j about 0, a_j is the importance of belief j, and N is the number of beliefs about 0.

Rosenberg [86] using a consistency principle, predicted that affect (the amount of liking) attached to an object would be highly related to the perceived instrumentality of the object, i.e. the judged probability that the object would lead to, or block, attainment of valued states and the value importance, i.e. the intensity of affect expected from these valued states. Stated mathematically, Rosenberg's model is

$$A_{ik} = \sum_{j=1}^{N} (PI_{ijk} VI_{ij}) \qquad (4\text{-}51)$$

where

A_{ik} = attitude toward an object k expressed in terms of an individual i's degree of like-dislike of that object.

PI_{ijk} = individual i's perceived instrumentality of the k*th* object toward attaining or blocking the j*th* goal or value.

VI_{ij} = value importance to an individual i of the j*th* goal or value.

Similar theories are proposed by Smith [97], Cartwright [23], Zajonc [110] and Peak [84]. Fishbein notes that "the important point is that all of them essentially lead to the hypothesis that an individual's attitude toward any object is a function of his beliefs about the object and the evaluative aspects of those belifs" [43, p.395]. However, marketing researchers have selected the Fishbein model to evaluate experimentally and therefore most research in the marketing area pertaining to attitudes of consumers has aimed at evaluating and validating the Fishbein model.

In the recent literature there has been a controversy over whether or not the predictive power of a simple model of perceived instrumentality without value importance (Model 2) is better than the predictive power of the Fishbein Model (Model 1):

$$\text{Model 1:} \quad A_{ik} = \sum_j PI_{ijk} \cdot VI_{ij}$$

$$\text{Model 2:} \quad A_{ij} = \sum_j PI_{ijh}$$

Sheth and Talarzyk [94],Lutz and Howard [77], and Moinpour and MacLachlan [80] all report that the inclusion of importance weights decreases the predictive power of the model and thus Model 2 was seen as a better predictor of brand preference than Model 1. Little difference in predictive power between the two models was found by Hansen and Bolland [55], Cohen and Houston [29], Scott and Bennett [92], Hughes and Guerrero [59], Churchill [27], Wilkie and Weinreich [109], and Beckwith and Lehmann [17]. Finally, increases in predictive power were illustrated by Model 1 by Anderson and Fishbein [5], Hansen [54], Lehmann

[74], Bass, Pessemier, and Lehmann [11], Bass and Talarzyk [13], Hoepfl and Huber[57]. However, a review and analysis of the above studies by Bass and Wilkie [14] found major differences in the methods of analysis which appear to have led to different conclusions. The use of cross-sectional information in making predictions of preference, as opposed to using information from individual consumers to predict preference for brands for individual consumers, has led to lowering the predictive power of Model 1. In addition, normalizing the data was found to increase the predictive power of Model 1. The interested reader is referred to a paper by Wilkie and Pessemier [108] which reviews 33 marketing studies related to the Fishbein model.

Next, it is shown that a goal programming model of a zero-one purchase decision and a Fishbein product selection model predict the same decision by an individual when a product's attributes are less than or equal to the ideal levels.

Let

$\underline{G}_c$ be a ($r \times 1$) vector of product attributes which represent the perceived instrumentality values of the organization's product.

$\underline{G}_{alt}$ be a ($r \times 1$) vector of product attributes which represent the perceived instrumentality values of the best available alternative.

$\underline{v}^-$ be a ($1 \times r$) vector of weights representing the value importance of attaining the $j=1,2,\ldots,r$ goals or ideal levels.

$\underline{n}$ be a ($r \times 1$) vector representing r goal or ideal levels desired by the client.

$\underline{y}^-$ be a ($r \times 1$) vector representing negative deviations from the ideal levels.

Then a Fishbein selection model which considers the organization's product and the best available alternative may be written as

$$\max[(\underline{v}^{-}\underline{G}_c)\alpha_1 + (\underline{v}^{-}\underline{G}_{alt})\alpha_2] \tag{4-52}$$

$$\alpha_1 \quad + \quad \alpha_2 = 1 \tag{4-53}$$

$$\alpha_1, \quad \alpha_2 = 0,1 \tag{4-54}$$

where α_1, α_2 are scalars which represent selection of the organization's product (α_1=1, α_2=0) or the best available alternative (α_1=0, α_2=1). Since none of the product attributes are assumed to exceed any ideal level and only one product may be selected, it can easily be seen that positive deviations from the ideal level are non-existent and what has been termed a "one-sided goal programming problem" [40] can be stated as:

$$\min \ \underline{v}^{-}\underline{y}^{-} \tag{4-55}$$

$$\underline{G}_c\alpha_1 + \underline{G}_{alt}\alpha_2 + \underline{y}^{-} = \underline{n} \tag{4-56}$$

$$\alpha_1 \quad + \quad \alpha_2 \quad = 1 \tag{4-53}$$

$$\alpha_1, \quad \alpha_2 \quad = 0,1 \tag{4-54}$$

<u>Lemma</u>. If the perceived instrumentality of a product's attribute j, j=1,2,...,r of achieving an ideal goal level n_j, j=1,2,...,r, is less than or equal to that ideal level, then the Fishbein selection model

and the one-sided goal programming model are identical.

Proof. Rewriting (4-56) as

$$\underline{y}^- = \underline{n} - \underline{G}_c\alpha_1 - \underline{G}_{alt}\alpha_2,$$

the goal programming model can be stated as

$$\min \underline{v}^-(\underline{n}-\underline{G}_c\alpha_1-\underline{G}_{alt}\alpha_2)$$

$$\alpha_1 + \alpha_2 = 1$$

$$\alpha_1, \quad \alpha_2 = 0,1.$$

Since $\underline{v}^-\underline{n}$ is a constant it can be dropped, so that the problem becomes

$$\min[-(\underline{v}^-\underline{G}_c)\alpha_1-(\underline{v}^-\underline{G}_{alt})\alpha_2]$$

$$\alpha_1 + \alpha_2 = 1$$

$$\alpha_1, \quad \alpha_2 = 0,1$$

or

$$\max[(\underline{v}^{-}\underline{G}_c)\alpha_1 + (\underline{v}^{-}\underline{G}_{alt})\alpha_2]$$

$$\alpha_1 \quad + \quad \alpha_2 = 1$$

$$\alpha_1, \quad \alpha_2 = 0,1$$

which is the Fishbein selection model. Q.E.D.

The above proposition, relating the one-sided goal programming model and the Fishbein model, illustrates that a goal programming model is in line with current research in the marketing area. Actually, the standard goal programming model may be considered more general in the sense that it allows for an individual to be dissatisfied (exhibit dislike) for a product whose attribute levels exceed the desired or ideal levels.

Of course the measurement of attitude toward an object (Fishbein Model) or the measurement of product or service dissatisfaction (goal programming model) does not necessarily provide proof that the object or service will be bought or utilized. Howard and Sheth [58] propose that "intention" to purchase follows attitude formation and precedes the overt act of purchasing or using the specific brand. However, it is difficult to determine intention and purchase or utilization in the planning phase. Thus,the organization is led to use the choice criteria or needs level and the client's evaluation for the purpose of producing a more acceptable product or service.

A Preferential Information Model (Zero-One Utilization)

In a situation in which the client has a zero-one decision (Problem I with constraint (4-42) replaced by α_1=0,1 and α_2=0,1), the introduction of integer utilization variables present difficulties since dual variables associated with the integer part of the problem do not provide the same information as the dual variables associated with the linear problem [9]. Although there have been investigations which have dealt with changes in the constraint vector ($\underline{n}$) and changes in the coefficients in the objective function [21], this author could not find any published research dealing with changes in the product output vector ($\underline{G}_c$). Thus, it is necessary to take a slightly different approach in attempting to determine an appropriate organizational output.

First of all, it should be mentioned that if the client responds with an $\alpha_1 = 1$, then the organization has no problem. However, if client utilization is zero and the organization desires to have a utilization of one, then there would exist a problem for the organization since it desires to have its product bought or utilized.

There are basically two approaches that the organization might take if $\alpha_1 = 0$: (1) attain information about the choice criteria and the respective need levels, or (2) attain information about the best available alternative. If the second approach is taken, the organization might attempt to produce an output comparable to the best available alternative (in one sense this would be an attempt to duplicate the competitor's output).

Of course the first approach would be preferable since it is basically an attempt to get information which could be used in producing an output which would satisfy the need levels of the client. This approach would always be taken if the organization were able to determine ideal need levels and client priorities. If this were the case, then Problems I and II would not be needed. The attempt to attain preferential information is essentially the approach taken in marketing studies when researchers ask the respondents to describe an "ideal" brand. If the central unit could attain information about the "ideal" attribute levels $\underline{n}$ and the weights associated with the positive and negative deviations from the ideal levels $(\underline{v}^+,\underline{v}^-)$, then using the same notation as for Problem I, the problem facing the organizational system would be:

Problem III

$$\min\{\sum_k (\underline{w}^+_{fk}\underline{d}^+_{fk}+\underline{w}^-_{fk}\underline{d}^-_{fk}+\underline{w}^+_{ak}\underline{d}^+_{ak}+\underline{w}^-_{ak}\underline{d}^-_{ak}+\underline{w}^+_{ck}\underline{d}^+_{ck}+\underline{w}^-_{ck}\underline{d}^-_{ck}) + (\underline{\underline{v}}\underline{h}^+ + \underline{v}^-\underline{h}^-)\} \quad (4\text{-}55)$$

subject to

$$\left.\begin{array}{ll} \sum_i \underline{p}^f_{ik}x_{ik} - I\underline{d}^+_{fk} + I\underline{d}^-_{fk} - I\underline{\underline{g}}^f_k = \underline{0} \\ \sum_i \underline{p}^a_{ik}x_{ik} - I\underline{d}^+_{ak} + I\underline{d}^-_{ak} = \underline{\underline{g}}^a_k \\ \sum_i \underline{p}^c_{ik}x_{ik} - I\underline{d}^+_{ck} + I\underline{d}^-_{ck} - I\underline{\underline{g}}^c_k = \underline{0} \\ \sum_i \underline{p}^\ell_{ik}x_{ik} \le \underline{\underline{g}}^\ell_k \end{array}\right\} k=1,2,\ldots,K \quad (4\text{-}56)$$

$$\sum_k P_k\underline{\underline{g}}^f_k \ge \underline{G}_f \quad (4\text{-}57)$$

$$\sum M_k \underline{g}_k^c - I\underline{h}^+ + I\underline{h}^- = \underline{n} \qquad (4\text{-}58)$$

$$\left.\begin{array}{l} \underline{d}_{fk}^+ \underline{d}_{fk}^- \geq \underline{0} \\ \underline{d}_{ak}^+ \underline{d}_{ak}^- \geq \underline{0} \\ \underline{d}_{ck}^+ , \underline{d}_{ck}^- \geq \underline{0} \end{array}\right\} \text{ for all } k \qquad (4\text{-}59)$$

$$x_{ik} \geq 0 \quad \text{for all } i, \text{ all } k \qquad (4\text{-}60)$$

$$0 \leq \underline{g}_k^c \leq \underline{b}_k \quad \text{for all } k \qquad (4\text{-}61)$$

$$\underline{h}^+, \underline{h}^- \geq 0 \qquad (4\text{-}62)$$

where $\underline{h}^+, \underline{h}^-$ are used instead of $\underline{y}^+$, $\underline{y}^-$ to differentiate between deviations without considering the best available alternative and deviations considering the best available alternative.

Letting $\underline{Y}_k$, $\underline{W}_k$, $\underline{\pi}_k$, F_k, A_k, C_k and L_k for $k=1,2,\ldots,K$ be defined as in Problem I and defining the set $(\underline{g}_k^f, \underline{g}_k^c)$ as

$$S(III) = \{(\underline{g}_k^f, \underline{g}_k^c): \sum_k P_k \underline{g}_k^f \geq \underline{G}_f; \quad 0 \leq \underline{g}_k^c \leq b_k, \quad k=1,2,\ldots,K\},$$

Problem III can be written as

Problem III-1

$$\min\{\sum_k \underline{W}_k \underline{Y}_k + (\underline{v}^- \underline{h}^- + \underline{v}^+ \underline{h}^+)\} \tag{4-63}$$

$$\text{subject to} \begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k - \begin{bmatrix} I\underline{g}_k^f \\ 0 \\ I\underline{g}_k^c \\ 0 \end{bmatrix} \begin{cases} = 0 \\ = \underline{g}^a \\ = 0 \\ \geq -\underline{g}_k^\ell \end{cases}, \quad k=1,2,\ldots,K \tag{4-64}$$

$$\sum M_k \underline{g}^c - I\underline{h}^+ + I\underline{h}^- = \underline{n} \tag{4-58}$$

$$\underline{Y}_k \geq 0 \quad \text{for all } k \tag{4-65}$$

$$(\underline{g}_k^f, \underline{g}_k^c) \leq S(III)$$

For a fixed $(\underline{g}_k^f, \underline{g}_k^c) = (\underline{g}_k^{ft}, \underline{g}_k^{ct}) \in S(III)$, the problem becomes

Problem III^t

$$\min\left(\sum_k \underline{W}_k \underline{Y}_k\right) \tag{4-66}$$

$$\text{subject to} \quad \begin{bmatrix} F_k \\ \\ A_k \\ \\ C_k \\ \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^{ft} \\ \\ = \underline{g}_k^{a} \\ \\ = \underline{g}_k^{ct} \\ \\ \geq -\underline{g}_k^{\ell} \end{cases}, \quad k=1,2,\ldots,K \tag{4-67}$$

$$\underline{Y}_k \geq 0 \quad \text{for all } k \tag{4-65}$$

Note that for a fixed $\underline{g}_k^c$, the value $(\underline{v}^-\underline{h}^-+\underline{v}^+\underline{h}^+)$ is specified and $(\underline{v}^-\underline{h}^-+\underline{v}^+\underline{h}^+)$ along with Equation (4-58) are not required in stating the problem.

As before, with $(\underline{g}_k^f,\underline{g}_k^c)$ fixed, Problem III^t is separable into K problems of the form:

<u>Problem A_k^t</u> for each k=1,2,...,K

$$\min z_k(\underline{g}_k^{ft},\underline{g}_k^{ct}) = \underline{W}_k\underline{Y}_k \tag{4-68}$$

$$\begin{bmatrix} F_k \\ A_k \\ C_k \\ -L_k \end{bmatrix} \underline{Y}_k \begin{cases} = \underline{g}_k^{ft} \\ = \underline{g}_k^{a} \\ = \underline{g}_k^{ct} \\ \geq -\underline{g}_k^{\ell} \end{cases} \tag{4-69}$$

$$\underline{Y}_k \geq 0 \tag{4-70}$$

Using the same procedure for the transforming Problem III as was used in Problem 0, making Assumption 1 to eliminate extreme rays from the Dual D_k^t, and noting that $(\underline{v}^+\underline{h}^+ + \underline{v}^-\underline{h}^-)$ and constraint (4-58) are necessary only when solving for $\underline{g}_k^c$, Problem III can be expressed as:

<u>Problem III-2</u>

$$\min[\sum_k \sigma_k + (\underline{v}^+\underline{h}^+ + \underline{v}^-\underline{h}^-)] \tag{4-71}$$

subject to

$$\sigma_k \geq z_k^*(\underline{g}_k^{fS_k},\underline{g}_k^{cS_k}) - \underline{\pi}_k^{fS_k}\underline{g}_k^{fS_k} - \underline{\pi}_k^{cS_k}\underline{g}_k^{cS_k} + \underline{\pi}_k^{fS_k}\underline{g}_k^{f} + \underline{\pi}_k^{cS_k}\underline{g}_k^{c} \tag{4-72}$$

for S_k=1,2,...,E_k, k=1,2,...,K

$$\sum_k M_k \underline{\underline{g}}_k^c - I\underline{h}^+ + I\underline{h}^- = \underline{n} \qquad (4\text{-}58)$$

$$\sum P_k \underline{\underline{g}}_k^f \geq \underline{G}_f \qquad (4\text{-}57)$$

$$0 \leq \underline{\underline{g}}_k^c \leq \underline{b}_k \quad \text{for all } k \qquad (4\text{-}61)$$

$$\underline{h}^+, \underline{h}^- \geq \underline{0} \qquad (4\text{-}62)$$

where the constraints of the form (4-72) can be generated as and when necessary by using $z_k^*(\underline{\underline{g}}_k^{ft}, \underline{\underline{g}}_k^{ct})$ $\underline{\pi}_k^{ft}$, $\underline{\pi}_k^{ct}$ from Problem A_k^t.

The solution procedure for solving Problem III is identical to Problem 0 given Assumption 1 with the following changes:

1. The constraint $\sum_k M_k \underline{\underline{g}}_k^c \geq \underline{G}_c$ is replaced by (4-58), (4-61) and (4-62).

2. The central unit solves a problem of the form Problem III-2 instead of Problem 0-4.

To allow the central unit to trade-off internal tension and "ideal product dissatisfaction" $(\underline{v}^+\underline{h}^+ + \underline{v}^-\underline{h}^-)$, trade-offs weights Q_1 and Q_2 may be assigned so that at any iteration T, the central unit would solve a problem of the form:

Problem III-5

$$\min\ [Q_1(\sum_k \sigma_k) + Q_2(\underline{v}^+\underline{h}^+ + \underline{v}^-\underline{h}^-)] \tag{4-73}$$

subject to $\sigma_k \geq z_k^*(\underline{g}_k^{ft}, \underline{g}_k^{ct}) - \underline{\pi}_k^{ft}\underline{g}_k^{ft} - \underline{\pi}_k^{ct}\underline{g}_k^{ct} + \underline{\pi}_k^{ft}\underline{g}_k^{f} + \underline{\pi}_k^{c}\underline{g}_k^{c}$ (4-74)

for $t=1,2,\ldots,T,\quad k=1,2,\ldots,K$

$$\sum_k M_k\underline{g}_k^c - I\underline{h}^+ + I\underline{h}^- = \underline{n} \tag{4-58}$$

$$\sum_k P_k\underline{g}_k^f \geq \underline{G}_f \tag{4-57}$$

$$0 \leq \underline{g}_k^c \leq \underline{b}_k \quad \text{for all } k \tag{4-61}$$

$$\underline{h}^+,\ \underline{h}^- \geq \underline{0} \tag{4-62}$$

If the $\underline{p}_{ik}$ could be selected from a convex set J_{ik} for Problem III, then project redesign could easily be incorporated into the solution procedure as described in an earlier section.

Summary

In this chapter several normative models of an organizational decision system are developed. A model in which the client is implicitly considered, is developed based on Freeland's goal partitioning procedure. Minimum satisfaction levels for both the central unit and the client are used to determine goals for the management units. The objective function of the overall problem stresses minimization of the sum of weighted deviations from management unit goals. Thus the management units are the focal point and the central unit and client only introduce lower limit constraints. This model appears to be analogous to Baker's general analytical model of resource allocation.

Based on the assumption that the client should have an impact upon decisions made within the organization, two types of information, directional and preferential, are defined and used as the basis for explicitly including the client in organizational decision system models.

Directional information from the client is used by the organization to determine the changes which would increase the acceptability of the output by the client. Preferential information from the client consists of preferred attribute levels that it would be desirable for the output to have.

Directional information for the purpose of making an output more acceptable to a client was seen as necessary when the organization is unable to ascertain preferred or "ideal" need levels of the client and the priorities associated with those levels. Consequently, a case termed partial utilization was discussed and two resulting mathematical programming models were presented. The objective function for the models included both the total internal tension (sum of weighted deviations from goals) and client dissatisfaction with available outputs. The available outputs consisted of the output of the organization and the best available alternative.

The first model was designed to allow the actual output of each management unit to deviate from the client-oriented goals. The second allowed no deviation. A goal partitioning approach was used to decompose the overall problems and it was found that the client may be treated as an additional subordinate unit. It was noted, however, that in the first model the procedure required the client to evaluate proposed output, not actual output, from the organization. Therefore, a second model, which did not allow the management units to deviate from client-oriented goals, was proposed. From a behavioral standpoint, one of the difficulties associated with the solution procedure is that the client interacts with the organization each time the management units interact with the central unit. In many situations, the interaction between the central unit and management unit is completed before interaction with a client begins. Descriptive models are presented in Chapter VI which attempt to alleviate some of the descriptive shortcomings of the models presented in this chapter.

If projects may be redesigned, then a criterion for specifying the preferred attributes of a redesigned project is developed. A solution procedure based on generalized linear programming, is incorporated in the partial utilization models to allow for redesign.

Several observations which related not only the end results of the procedure but also the means by which the system operated to extreme forms of behavior in actual organizations were presented.

Preferential information for the purpose of determining the attributes of a product or service which are as close as possible to a client's ideal was used as a basis for developing a third model which explicitly includes the client. Again based on a goal partitioning scheme, the central unit was viewed as attempting to determine central unit oriented goals and client-oriented goals for each management unit so that the total internal tension plus weighted deviations from a client's desired output is minimized.

In the models discussed in this chapter, a basic assumption was that only one client or one group of clients with homogeneous needs interacted with the organization. In the next chapter, three models are considered when the organization serves several individuals or groups.

CHAPTER V

MULTI-CLIENT ORGANIZATIONAL DECISION SYSTEM MODELS

Introduction

The organizational system models in the last chapter are composed of three primary groups: the central unit, the management unit, and the client. They are based on an assumption that the client is one individual or a group of individuals whose needs (or more specifically, need levels) are homogeneous. In addition, the organization is seen as producing one product or providing one service.

This chapter introduces the concept of multi-client or multiple groups of clients. Three decision rules for determining the organization's output are discussed when the output again consists of producing one product or providing one service. In the multi-client situation, the number of need levels are assumed to be the same as are the need dimensions but the values of the need levels and the weights assigned to deviations are assumed to vary for each client. In the multiple group situation, the need levels within a group are assumed homogeneous, whereas the need levels between groups are assumed heterogeneous. Thus both situations are similar in nature.

An Organizational System with Multiple Client Groups

Assume that the organization's output is of interest to J potential client groups. A client group j is assumed to have a number of ideal need levels, described by the (r×l) vector $\underline{n}_j$, which may be satisfied by purchasing or using the output of the organization. The organization is thus faced with the problem of determining the characteristics of its single output when a number of different need levels $\{\underline{n}_1, \underline{n}_2, \ldots, \underline{n}_J\}$ are desired by the clients. The above assumption reflects the change in marketing research from describing consumers on the basis of geographic and demographic factors to describing consumers on the basis of sociological and psychological characteristics.

> In recent years market research has made substantial progress in describing consumers. It no longer lists merely the demographic attributes, but also more and more social and psychological attributes of the consumers, it no longer simply describes requirements, but goes into needs, desires, and their interconnections. For this purpose a number of strongly differentiated consumer typologies have been produced of late [112, p.482].

Zernish [111] emphasizes the trend toward close contact with the consumer in product development. In a study of the "subcompact" automobile market, Teach and Neidell [101] used cluster analysis and nonmetric multidimensional scaling to develop "psychological market segments. This study is a contrast to most market segmentation studies which use demographic and/or geographic locations of customers. The authors note:

> Whenever a product faces a large number of buyers, it is generally possible to divide the buyers into separate groups or segments. Each segment is designed to be as homogeneous as possible while at the same time the differences between the segments are as great as possible. The result is that the people in each segment look for different attributes in the product they buy to satisfy their specific needs and desires. The benefit of segmentation is at least three fold.
>
> 1) Marketing management is in a better position to spot and compare opportunities.

2) The seller can use his knowledge of response functions for each of the segments to guide the allocation of his marketing budget.

3) The seller can make finer adjustments of his product and market appeals. Instead of s "shot gun" approach covering vast heterogenous groups of customers he can use a "rifle" approach. He can take careful aim to the specific needs and wants of one or more particular segments [101, pp. 7,10].

Thus, it can be seen that the assumptions in this dissertation related to client groups are in concordance with those in one current marketing research area.

The next three sections present three mathematical models for determining the characteristics of an organization's output when there exist multiple groups of clients which can be described or segmented in terms of their needs.

Minimizing the Sum of Internal Tension and Weighted Client Group Dissatisfaction

In the first model to be discussed, the organization is seen as attempting to minimize internal tension plus the sum of weighted client dissatisfaction with the organization's output subject to organizational goals and constraints. It is assumed that the central unit has knowledge of the ideal attribute levels $\underline{n}_j$ for each client group $j=1,2,...,J$. Using the same notation as in Chapter IV, the problem for the central unit may be stated as:

Problem IV

$$\min\{\sum(\underline{w}^{+}_{fk}\underline{d}^{+}_{fk}+\underline{w}^{-}_{fk}\underline{d}^{-}_{fk}+\underline{w}^{+}_{ak}\underline{d}^{+}_{ak}+\underline{w}^{-}_{ak}\underline{d}^{-}_{ak}+\underline{w}^{+}_{ck}d^{+}_{ck}+w^{-}_{ck}d^{-}_{ck})$$

$$+\sum_{j} N_{j}(\underline{v}^{+}_{j}\underline{h}^{+}_{j}+\underline{v}^{-}_{j}\underline{h}^{-}_{j})\} \qquad (5\text{-}1)$$

subject to

$$\left.\begin{aligned}
&\sum_{i} \underline{p}^{f}_{ik} - I\underline{d}^{+}_{fk} + I\underline{d}^{-}_{fk} - I\underline{g}^{f}_{k} &&= \underline{0}\\
&\sum_{i} \underline{p}^{a}_{ik}x_{ik} - I\underline{d}^{+}_{ak} + I\underline{d}^{-}_{ak} &&= \underline{g}^{a}_{k}\\
&\sum_{i} \underline{p}^{c}_{ik}x_{ik} - I\underline{d}^{+}_{ck} + I\underline{d}^{-}_{ck} - I\underline{g}^{c}_{k} &&= \underline{0}\\
&\sum_{i} \underline{p}^{\ell}_{ik}x_{ik} &&\le \underline{g}^{\ell}_{k}
\end{aligned}\right\} k = 1,2,\ldots,K \qquad (5\text{-}2)$$

$$\left.\begin{aligned}
&\sum_{k} M_{k}\underline{g}^{c}_{k} - I\underline{h}^{+}_{j} + I\underline{h}^{-}_{j} = \underline{n}_{j}\\
&\underline{h}^{+}_{j}, \quad \underline{h}^{-}_{j} \ge \underline{0}
\end{aligned}\right\} \text{for } j = 1,2,\ldots,J \qquad (5\text{-}3)$$

$$\sum_{k} P_{k}\underline{g}^{f}_{k} \ge \underline{G}_{f} \qquad (5\text{-}4)$$

$$\underline{0} \le \underline{g}^{c}_{k} \le \underline{b}_{k} \quad \text{for all } k \qquad (5\text{-}5)$$

$$\left.\begin{array}{l} \underline{d}^{+}_{fk},\underline{d}^{-}_{fk} \geq \underline{0} \\ \\ \underline{d}^{+}_{ak},\underline{d}^{-}_{ak} \geq \underline{0} \\ \\ \underline{d}^{+}_{ck},\underline{d}^{-}_{ck} \geq \underline{0} \end{array}\right\} \text{ for all } k \tag{5-6}$$

$$x_{ik} \geq 0 \quad \text{for all } i, \text{ for all } k \tag{5-7}$$

where N_j, $j=1,2,\ldots,J$ is a scalar weighting factor assigned by the central unit to group j. N_j may refer to the number of individuals in group j or to the relative importance of group j with respect to the other groups.

Problem IV is similar to Problem III discussed in Chapter IV. In this situation, even though there are J client groups, instead of only one, fixing $\underline{\underline{g}}^{c}_{k}$ fixes $\sum N_j(\underline{v}^{+}_{j}\underline{h}^{+}_{j}+\underline{v}^{-}_{j}\underline{h}^{-}_{j})$. Therefore, a goal partitioning scheme can be used to solve Problem IV. Recognizing that with $(\underline{\underline{g}}^{f}_{k},\underline{\underline{g}}^{c}_{k})$ fixed, each management unit can be viewed as solving Problem A^{t}_{k}, described in Chapter IV, the following solution procedure, given Assumption 1 of Chapter IV, can be stated:

Step 1. The central unit arbitrarily selects goal levels $\underline{\underline{g}}^{f}_{k} = \underline{\underline{g}}^{f1}_{k} < \infty$ and $\underline{\underline{g}}^{c}_{k} = \underline{\underline{g}}^{c1}_{k} < \infty$ for $k=1,2,\ldots,K$ such that $\sum P_k\underline{\underline{g}}^{f1}_{k} \geq \underline{G}_f$ and $\underline{0} \leq \underline{\underline{g}}^{c1}_{k} \leq \underline{b}_k$ for all k. Initially set $\sigma_k = \sigma_k = -\infty$ for $k=1,2,\ldots,K$. The $(\underline{\underline{g}}^{f1}_{k},\underline{\underline{g}}^{c1}_{k})$ for $k=1,2,\ldots,K$ is sent to the respective management unit.

Step 2. Each management unit solves Problem A_k^1 and determines the optimal values $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1})$, $\underline{\pi}_k^{f1}$ and $\underline{\pi}_k^{c1}$. Due to Assumption 1, $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1}) > -\infty$. The optimal values are sent to the central unit.

Step 3. Since $z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1}) > \sigma_k^1 = -\infty$, the central unit solves the following problem:

<u>Problem IV-1</u>

$$\min[\sum_k \sigma_k + \sum_j N_j(\underline{v}_j^+\underline{h}_j^+ + \underline{v}_j^-\underline{h}_j^-)]$$

$$\text{subject to} \quad \sigma_k \geq z_k^*(\underline{g}_k^{f1},\underline{g}_k^{c1}) - \underline{\pi}_k^{f1}\underline{g}_k^{f1} - \underline{\pi}_k^{c1}\underline{g}_k^{c1} + \underline{\pi}_k^{f1}\underline{g}_k^{f} + \underline{\pi}_k^{c1}\underline{g}_k^{c}, \text{ for all } k$$

$$\sum_k M_k\underline{g}_k^c - I\underline{h}_j^+ + I\underline{h}_j^- = \underline{n}_j, \quad j=1,2,\ldots,J$$

$$\underline{h}_j^+, \quad \underline{h}_j^- \geq 0 \quad \text{for all } j$$

$$\sum P_k\underline{g}_k^f \geq \underline{G}_f; \quad \underline{0} \leq \underline{g}_k^c \leq \underline{b}_k \quad \text{for all } k$$

The solution of Problem IV-1 yields σ_k^2, k=1,2,...,K and $(\underline{g}_k^{f2},\underline{g}_k^{c2})$, k=1,2,...,K. The $(\underline{g}_k^{f2},\underline{g}_k^{c2})$ are sent to the respective management unit.

At iteration T-1

Step 4. The central unit would solve the following problem:

Problem IV-2

$$\min\Big[\sum_k \sigma_k + \sum_j N_j(\underline{v}_j^+\underline{h}_j^+ + \underline{v}_j^-\underline{h}_j^-)\Big] \tag{5-8}$$

subject to

$$\sigma_k \geq z_k^*(\underline{\underline{g}}_k^{ft}, \underline{\underline{g}}_k^{ct}) - \underline{\pi}_k^{ft}\underline{\underline{g}}_k^{ft} - \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{ct} + \underline{\pi}_k^{ft}\underline{\underline{g}}_k^{f} + \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{c} \tag{5-9}$$

for $t=1,2,\ldots,T-1$

$k=1,2,\ldots,K$

$$\left.\begin{aligned} \sum_k M_k\underline{\underline{g}}_k^c - I\underline{h}_j^+ + I\underline{h}_j^- &= \underline{n}_j \\ h_j^+, \quad \underline{h}_j^- &\geq 0 \end{aligned}\right\} \; j=1,2,\ldots,J \tag{5-10}$$

$$\sum_k P_k\underline{\underline{g}}_k^f \geq \underline{G}_f \tag{5-11}$$

$$\underline{0} \leq \underline{\underline{g}}_k^c \leq \underline{b}_k \quad \text{for all } k \tag{5-12}$$

The resulting optimal values σ_k^T and $(\underline{\underline{g}}_k^{fT}, \underline{\underline{g}}_k^{cT})$ are found and $(\underline{\underline{g}}_k^{fT}, \underline{\underline{g}}_k^{cT})$ is sent to management unit k.

Step 5. Management unit k solves Problem A_k^T and the values $z_k^*(\underline{\underline{g}}_k^{fT}, \underline{\underline{g}}_k^{cT})$, $\underline{\pi}_k^{fT}$, $\underline{\pi}_k^{cT}$ are sent to the central unit.

Step 6. The central unit checks to determine if any $z_k^*(\underline{\underline{g}}_k^{fT}, \underline{\underline{g}}_k^{cT}) > \sigma_k^T$ for $k=1,2,\ldots,k$. If an inequality exists, then a constraint of the form (5-9) is added. Return to Step 4. If

$z_k^*(\underline{g}_k^{fT}, \underline{g}_k^{cT}) \le \sigma_k^T$ for k=1,2,...,K, then stop. An optimal solution has been found to Problem IV.

Once again, the central unit may apply trade-off weights Q_1 and Q_2 to the objective function so that (5-8) becomes

$$\min[Q_1(\sum_k \sigma_k) + Q_2(\sum_j N_j(\underline{v}_j^+\underline{h}_j^+ + \underline{v}_j^-\underline{h}_j^-)] \tag{5-13}$$

The following comments are helpful in viewing the decision rule to summate the weighted client dissatisfaction:

1. If the central unit places a higher priority upon minimizing client dissatisfaction than upon minimizing internal tension ($Q_2 >>> Q_1$), then, during the central unit-administrator interaction, the administrator has little impact upon changing client-oriented goals and therefore the change in internal tension would be mainly dependent upon the administrator's influence upon funder-oriented goals.

2. If the central unit places a higher priority upon minimizing internal tension rather than client dissatisfaction, then the administrators would have a large impact upon both funder-oriented and client-oriented goals.

3. If the client need levels from the J groups are not clustered or do not have a unimodal type of distribution, then the resulting output from a summated weighted client dissatisfaction model may result in low utilization from all client groups.

Comment 3 deserves further explanation and a simple example should be helpful. Suppose $\underline{n}_j$ is unidimensional and there are six groups. If the ideal value for groups 1, 2, and 3 are 4, 4, and 3, respectively, and the ideal value for groups 4, 5, and 6 are 10, 11, and 10, respectively, and all N_j's are equal, then the proposed output might result in a value between 6 and 7. The value of the proposed output might then be considered too large for the first cluster (groups 1, 2, 3) and also too small for the second cluster (groups 4, 5,6). In such a situation, utilization from all groups may be low, in which case it may be advisable to concentrate either on the first cluster or on the second cluster.

Targeting a Client Group Which Minimizes the Sum of Internal Tension and Client Dissatisfaction

From the standpoint of attempting to minimize internal tension plus client dissatisfaction and selecting the client group which has the minimum dissatisfaction, the objective function of such a problem may be written as

$$\min\{\sum_k z_k(\underline{g}_k^f, \underline{g}_k^c) + \min_j(\underline{v}_j^+ \underline{h}_j^+ + \underline{v}_j^- \underline{h}_j^- / j=1,2,\ldots,J)\}$$

with the constraint set being the same as for Problem IV [i.e. (5-2)-(5-7)]. The solution to this problem would not only provide the minimum of internal tension and client dissatisfaction, but also provide the client group which has a minimum dissatisfaction. Thus, it would provide the client group which the organization would seek to satisfy (i.e. the target group). However, this objective function is non-convex and beyond the scope of this dissertation.

Therefore, in attempting to select a target group, consideration is given only to the minimum of the sum of internal tension and client dissatisfaction. That is, the group which is selected may not be the group which has the least amount of dissatisfaction. However, the group that is selected is the one which provides for the minimum value of internal tension plus client dissatisfaction.

In the following two subsections, two cases are considered. The first case is aimed at selecting a target group. The second case considers a situation in which a target group has been selected. In addition, for each case, there may or may not be a concern for the dissatisfaction levels of the groups which are not targeted.

Selecting a Target Group

Given $j=1,2,\ldots,J$ client groups, it is desirable to find the group $j=\hat{j}$ such that the sum of internal tension and client group dissatisfaction is a minimum. In order to select a group, it is necessary to solve J problems of the form:

Problem V(j), $j=1,2,\ldots,J$

$$\min\Big\{\sum_k(\underline{w}^+_{fk}\underline{d}^+_{fk}+\underline{w}^-_{fk}\underline{d}^-_{fk}+\underline{w}^+_{ak}\underline{d}^+_{ak}+\underline{w}^-_{ak}\underline{d}^-_{ak}+\underline{w}^+_{ck}\underline{d}^+_{ck}+\underline{w}^-_{ck}\underline{d}^-_{ck})$$

$$+\ (\underline{v}^+_j\underline{h}^+_j+\underline{v}^-_j\underline{h}^-_j)\Big\} \qquad (5\text{-}14)$$

subject to

$$\left.\begin{aligned}
\sum_i \underline{p}^f_{ik}x_{ik} - I\underline{d}^+_{fk} + I\underline{d}^-_{fk} - I\underline{\underline{g}}^f_k &= \underline{0}\\
\sum_i \underline{p}^a_{ik}x_{ik} - I\underline{d}^+_{ak} + I\underline{d}^-_{ak} &= \underline{\underline{g}}^a_k\\
\sum_i \underline{p}^c_{ik}x_{ik} - I\underline{d}^+_{ck} + I\underline{d}^-_{ck} - I\underline{\underline{g}}^c_k &= \underline{0}\\
\sum_i \underline{p}^\ell_{ik}x_{ik} &\le \underline{\underline{g}}^\ell_k
\end{aligned}\right\}\ k=1,2,\ldots,K \qquad (5\text{-}15)$$

$$\sum P_k \underline{g}_k^f \ge \underline{G}_f \tag{5-16}$$

$$\sum_k M_k \underline{g}_k^c - I h_j^+ + I \underline{h}_j^- = \underline{n}_j \tag{5-17}$$

$$h_j^+, \quad \underline{h}_j^- \ge \underline{0} \tag{5-18}$$

$$\left.\begin{array}{l} \underline{d}_{fk}^+, \underline{d}_{fk}^- \ge \underline{0} \\ \underline{d}_{ak}^+, \underline{d}_{ak}^- \ge \underline{0} \\ \underline{d}_{ck}^+, \underline{d}_{ck}^- \ge \underline{0} \end{array}\right\} \text{ for all } k \tag{5-19}$$

$$x_{ik} \ge 0 \quad \text{for all } i, \text{ for all } k \tag{5-20}$$

$$\underline{0} \le \underline{g}_k^c \le \underline{b}_k \quad \text{for all } k \tag{5-21}$$

One might note that there is no concern for groups other than the one currently being considered. Problem V(j) can be partitioned as was Problem III. Since it is desirable to select the group for which the objective function is the minimum of all optimal objective functions, a simple comparison of the optimal objective functions would reveal the group associated with the minimum value. If that group were $j=\hat{j}$, then the values of x_{ik} for all i and k, $\underline{g}_k^f$ and $\underline{g}_k^c$ associated with Problem $V(\hat{j})$ at optimality would be used.

If there is a concern for the dissatisfaction levels for groups other than the one which may finally be selected, then it would be desirable to keep the levels of dissatisfaction of the client groups below a certain level γ_j for j=1,2,...,J. The level γ_j would need to be predetermined by the central unit. Given concern for other groups, Problem V(j) may be modified by the addition of the following constraints:

$$\left.\begin{aligned} (\underline{v}_j^+\underline{h}_j^+ + \underline{v}_j^-\underline{h}_j^-) &\le \gamma_j \\ \sum_k M_k \underline{g}_k^c - I\underline{h}_j^+ + I\underline{h}_j^- &= \underline{n}_j \\ \underline{h}_j^+, \quad \underline{h}_j^- &\ge \underline{0} \end{aligned}\right\} \quad j=1,2,\ldots,J. \tag{5-22}$$

Problem V(j) with restriction (5-22) will be termed Problem V(j').

Restrictions (5-22) limit the guideline goal levels sent to the administrators. This type of model may be applicable to the public sector, a service organization, or a monopoly, where the organization seeks to serve one specific client while maintaining the level of dissatisfaction of other clients within certain bounds.

Although it may appear that an excessive amount of time and effort is required in determining the target client (J single client problems), it may be necessary for the organization to go through a "market survey" in order to determine which client the organization should seek to satisfy.

<u>Given a Target Group</u>

If the organization has selected a target group and has no concern for the other groups then the problem facing the organization may be described by Problem III in Chapter IV. On the other hand, concern for groups other than the target group may be incorporated by using Problem V(j') where the j used refers to the target group.

Of course, the central unit may desire to consider trade-off weights Q_1 and Q_2 for internal tension and client dissatisfaction in either case described in this section.

Minimizing the Sum of Internal Tension and Maximum Client Dissatisfaction

The final model to be discussed in the multi-client/single output situation is one in which the organization is attempting to minimize internal tension plus maximum client dissatisfaction. The objective function consists of terms related to the sum of weighted goal deviations of the management units and a term which specifies the largest value of dissatisfaction over all client groups. The problem may be stated as:

Problem VI

$$\min\{\sum_k(\underline{w}^+_{fk}\underline{d}^+_{fk}+\underline{w}^-_{fk}\underline{d}^-_{fk}+\underline{w}^+_{ak}\underline{d}^+_{ak}+\underline{w}^-_{ak}\underline{d}^-_{ak}+\underline{w}^+_{ck}\underline{d}^+_{ck}+\underline{w}^-_{ck}\underline{d}^-_{ck}) + \delta\} \tag{5-23}$$

subject to

$$\left.\begin{aligned}
\sum_i \underline{p}^f_{ik}x_{ik} - I\underline{d}^+_{fk} + I\underline{d}^-_{fk} - I\underline{g}_k &= \underline{0} \\
\sum_i \underline{p}^a_{ik}x_{ik} - I\underline{d}^+_{ak} + I\underline{d}^-_{ak} &= \underline{g}^a_k \\
\sum_i \underline{p}^c_{ik}x_{ik} - Id^+_{ck} + Id^-_{ck} - I\underline{g}^c_k &= \underline{0} \\
\sum_i \underline{p}^\ell_{ik}x_{ik} &\le \underline{g}^\ell_k
\end{aligned}\right\} \quad k=1,2,\ldots,K \tag{5-24}$$

$$\sum P_k \underline{g}_k^f \geq \underline{G}_f \tag{5-25}$$

$$\left.\begin{array}{r} \delta \geq \underline{v}_j^+ \underline{h}_j^+ + \underline{v}_j^- \underline{h}_j^- \\ \sum M_k \underline{g}_k^c - I h_j^+ + I \underline{h}_j^- = n_j \\ h_j^+, \quad h_j^- \geq 0 \end{array}\right\} \; j=1,2,\ldots,J \tag{5-26}$$

$$\underline{0} \leq \underline{g}_k^c \leq \underline{b}_k \quad k=1,2,\ldots,K \tag{5-27}$$

$$\left.\begin{array}{r} \underline{d}_{fk}^+, \underline{d}_{fk}^- \geq \underline{0} \\ \underline{d}_{ak}^+, \underline{d}_{ak}^- \geq \underline{0} \\ \underline{d}_{ck}^+, \underline{d}_{ck}^- \geq \underline{0} \end{array}\right\} \text{ for all } k \tag{5-28}$$

$$x_{ik} \geq 0 \quad \text{for all } i, \text{ for all } k \tag{5-29}$$

which may be solved by the goal partitioning procedure.

Once again, in certain situations, it may be desirable to place an upper bound on the levels of dissatisfaction for one or more client groups other than the one which is maximally dissatisfied. For example, in a service organization, such as a library, an attempt to decrease the level of dissatisfaction of one group of users may lead to an increase in the level of dissatisfaction of another group of users due to a reallocation of resources. Since the second group of users may be accustomed to the current level of service received, a reduction of services would be expected to produce an increase in client dissatisfaction. If client dissatisfaction increases beyond a critical amount, called a threshold level, the client may not tolerate the level of dissatisfaction and may take action which might have serious repercussions for the organization. In such a case, the central unit may establish threshold levels to insure that dissatisfaction for each client group stays below the critical amount. In order to take into account the existence of a threshold level for the client groups the following set of constraints may be added to Problem VI.

$$\underline{v}_j^+\underline{h}_j^+ + \underline{v}_j^-\underline{h}_j^- \le \gamma_j \quad j=1,2,\ldots,J \tag{5-30}$$

where γ_j is the central unit's perceived threshold level for client group.

Adding trade-off weights Q_1 and Q_2, the objective function for the central unit would be:

$$\min[Q_1(\sum_k \sigma_k) + Q_2(\delta)]$$

Summary

In this chapter, multiple client groups, which can be described or segmented on the basis of their respective need levels are introduced. If the organization is assumed to have a single output, three decision models of interest can be discussed. The first model describes the minimization of the sum of internal tension and weighted client group dissatisfaction. In the objective function, priorities, specified by the central unit, are assigned to the dissatisfaction levels of each client group. In this model it would appear desirable to have clients with ideal need levels which are in some sense clustered or unimodal.

The second model is related to selecting or having a target group. In selecting a target group, the group, which is targeted, is the one which minimizes the sum of internal tension plus the client dissatisfaction for that group. If the organization has concern for the dissatisfaction of all client groups, then additional constraints may be added in order to keep the dissatisfaction levels within bounds. If a target group has been specified,threshold levels of dissatisfaction can be maintained for the other groups by additional constraints.

The final model is related to the maximum client dissatisfaction over all groups. Thus the objective is to minimize internal tension plus maximum client dissatisfaction. As in the second model, it may be desirable to establish threshold levels for the client groups other than the one which is most dissatisfied.

All of the models discussed in this chapter may be considered normative in nature and can be partitioned in a manner similar to the approach used for Problem III. For each model, an optimal solution can be determined.

CHAPTER VI

DESCRIPTIVE MODELS OF THE INTERACTION PROCESS IN AN ORGANIZATIONAL SYSTEM

Introduction

In the last two chapters, solution procedures for several types of problems related to the resource allocation and goal setting process in an organizational system are examined. The solution procedures proposed in Chapter IV have two major disadvantages from a behavioral viewpoint: (1) interaction between the central unit and the client occurred at the same time that interaction between the central unit and management unit occurs, and (2) the client evaluates proposed output as opposed to actual output from the organization. In this chapter, several descriptive interactive models of the resource allocation and goal setting process are proposed which models differ from the previous models as follows:

1. Interaction between the central unit and management units continues until a "satisfactory" allocation of central unit oriented goals and client-oriented goals for each management unit is attained.

2. The output given to the client is based upon actual output of the management units and not upon the proposed output.

3. Actual output is not given to the client until a "satisfactory" allocation of goals for the management units is attained.

4. Project redesign may be based not only upon preferences of the management unit but also the preferences of the client.

5. The client may seek to interact not only with the central unit but also with the management units.

The differences noted above are more in line with a description of an actual process in an organizational system [7,8,50,95] and may be considered as descriptive models in contrast to the normative models in the previous chapters.

Let's consider each group in the organizational system separately along with the decision problem facing each group and the information that may be transferred to the other groups (the process itself is considered as an interactive one among the three major groups).

With respect to the client, again assume that he can specify a desired level for each choice criterion and the levels can be described by the vector $\underline{n}$, dimension ($r \times 1$). But now assume that the client is in a position to evaluate the *actual* output of the organization (defined by the ($r \times 1$) vector $\hat{\underline{G}}_c$) rather than the proposed output $\underline{G}_c$.

In the partial utilization case, the client's decision problem, using actual output and the same notation defined in Chapter IV, may be described using a goal programming formulation as:

Problem U

$$\min V(\hat{\underline{G}}_c) = (\underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-) \tag{6-1}$$

$$\text{subject to} \quad (\hat{\underline{G}}_c)\alpha_1 + G_{alt}\alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n} \tag{6-2}$$

$$\alpha_1 + \alpha_2 = 1 \tag{6-3}$$

$$\underline{y}^+, \quad \underline{y}^- \geq \underline{0} \tag{6-4}$$

$$\alpha_1, \alpha_2 \geq 0 \tag{6-5}$$

If, upon solving the above problem, the utilization variable $\alpha_1 = 1$, then the output would be fully utilized by the client and, with regard to the organization, the central unit and administrators should be satisfied with the client's utilization of the product or service. As a matter of fact, there may be some level $\alpha^* \leq 1$, such that if $\alpha_1 \geq \alpha^*$, the indivuals in the organization would be satisfied with the utilization of their product or service. However, if the resulting α_1 is zero, then the client would be fully utilizing the best available alternative and for $\alpha_1 < \alpha^*$, the organization would be dissatisfied with the client's utilization of the organization's product or service.

To take the analysis one step further, there may also exist an upper bound $\alpha^0 < 1$, on the utilization variable which the organization might desire to have utilization remain below. An upper bound may be desirable in order to avoid possible legal difficulties associated with having a monopoly. Thus the organization may desire to have the client's utilization within the range $\alpha^* \leq \alpha_1 \leq \alpha^0$. In the following discussion, it is assumed that $\alpha^0 = 1$. Let's now consider the reasons the client might change his utilization of the organization's product or service.

In order for the utilization of the organization's output to change, one or more of the following must occur: (1) the attributes of the best available alternative $\underline{G}_{alt}$ change, (2) the priorities $\underline{v}^+$, $\underline{v}^-$ change, (3) the criterion levels $\underline{n}$ change, or (4) the attributes of the organization's output $\hat{\underline{G}}_c$ change. It is assumed that the organization has no control over the attributes of the best available alternative $\underline{G}_{alt}$. It should be mentioned that there are instances where this assumption would not hold. For example, some companies provide product specifications to other companies in order to assure that there is a competitor. The $\underline{v}^-$, $\underline{v}^+$ or even the criterion levels $\underline{n}$ may be changed through such means as advertising and educating. But one obvious approach for the organization to undertake, in order to increase utilization, is to change the organization's output $\hat{\underline{G}}_c$. The question is: How should the organization's output change?

If the client would provide the organization with directional information regarding how the client's dissatisfaction with the available outputs (assuming that the client's objective function is a measure of need dissatisfaction) might change with changes in the attributes of the product or service, then the organization would, in a sense be guided by the client's needs.

Within the organization, the central unit--management unit interaction, in which the central unit is seen as attempting to establish goals for each management unit in order to minimize the total internal tension of the organization, takes place. If total internal tension is minimized, then "organizational optimality" is said to be achieved. It would then be necessary to determine if the output would be viewed as an improvement with respect to customer requirements. If no improvement is seen, then, using customer feedback, the administrators may attempt to redesign their alternatives subject to technological constraints in order to improve the output.

If the organization's output is viewed as an improvement with respect to customer requirements, then the organizational output is sent to the customer, who determines the amount of utilization. The customer would then provide feedback to the organization and the improvement process would repeat.

The feedback to the organization may be sent to the central unit, who, in turn, specifies client-oriented goals for each subordinate (termed indirect influence) or to the management units, who would determine the client-oriented goals themselves (termed direct influence). Interactive models incorporating both "indirect client influence" and "direct client influence" are presented in the following sections.

A description of the process for which models are developed is as follows:

a. Central unit—management unit interaction in order to determine goal guidelines for the management unit which consider total goal discrepancy dissatisfaction of the management units and client dissatisfaction.

b. Actual output is sent to the client for evaluation.

c. The central unit or management unit receives feedback from the client for the purpose of improving output.

d. A determination of whether or not the client utilization is satisfactory and, if satisfactory--stop; if not continue.

e. Central unit—management unit interaction to determine a new set of goal guidelines using customer feedback until there can be no further decrease in internal tension.

f. Central unit checks if the new output is "improved" with respect to customer requirements, and if "improved," return to (b), if not "improved," client information is used by the management unit for project redesign.

g. If feasible to redesign and "improve" output, return to (a); if not feasible to redesign and "improve" output, stop.

A diagram of the interaction process described above is presented in Figure 6.

Improving Organizational Output

Given an organizational output $\hat{\underline{G}}_c = \hat{\underline{G}}_c^1$ and the assumption that the client's selection process can be described by Problem U, let $(\underline{\beta}^1, \mu^1)$ be a $\left(1\times(r+1)\right)$ vector of optimal dual multipliers associated with Problem U. Using the simplex optimality criterion, if $(-\underline{\beta}\hat{\underline{G}}_c - \mu) < 0$, then it is possible to find a lower value of the objective function (i.e. lower dissatisfaction) by increasing the value of α_1.

The problem then becomes Problem U with a variable column vector $\hat{\underline{G}}_c$ if the organization is willing to change $\hat{\underline{G}}_c$. The client may influence the change by providing the organization with information regarding the dual variables. The actual output is assumed dependent upon the activity levels selected by the management units. Assuming that the management unit solves Problem A_k^t, the actual output related to the client is given by $\sum_i \underline{p}_{ik}^c x_{ik}$ for management unit k. The management unit outputs are then combined to form the actual client output by

$$\hat{\underline{G}}_c = \sum_k M_k\left(\sum_i \underline{p}_{ik}^c x_{ik}\right)$$

It will be useful to define the actual client-oriented output from management unit k by $\hat{\underline{g}}_k^c = \sum_i \underline{p}_{ik}^c x_{ik}$ thus

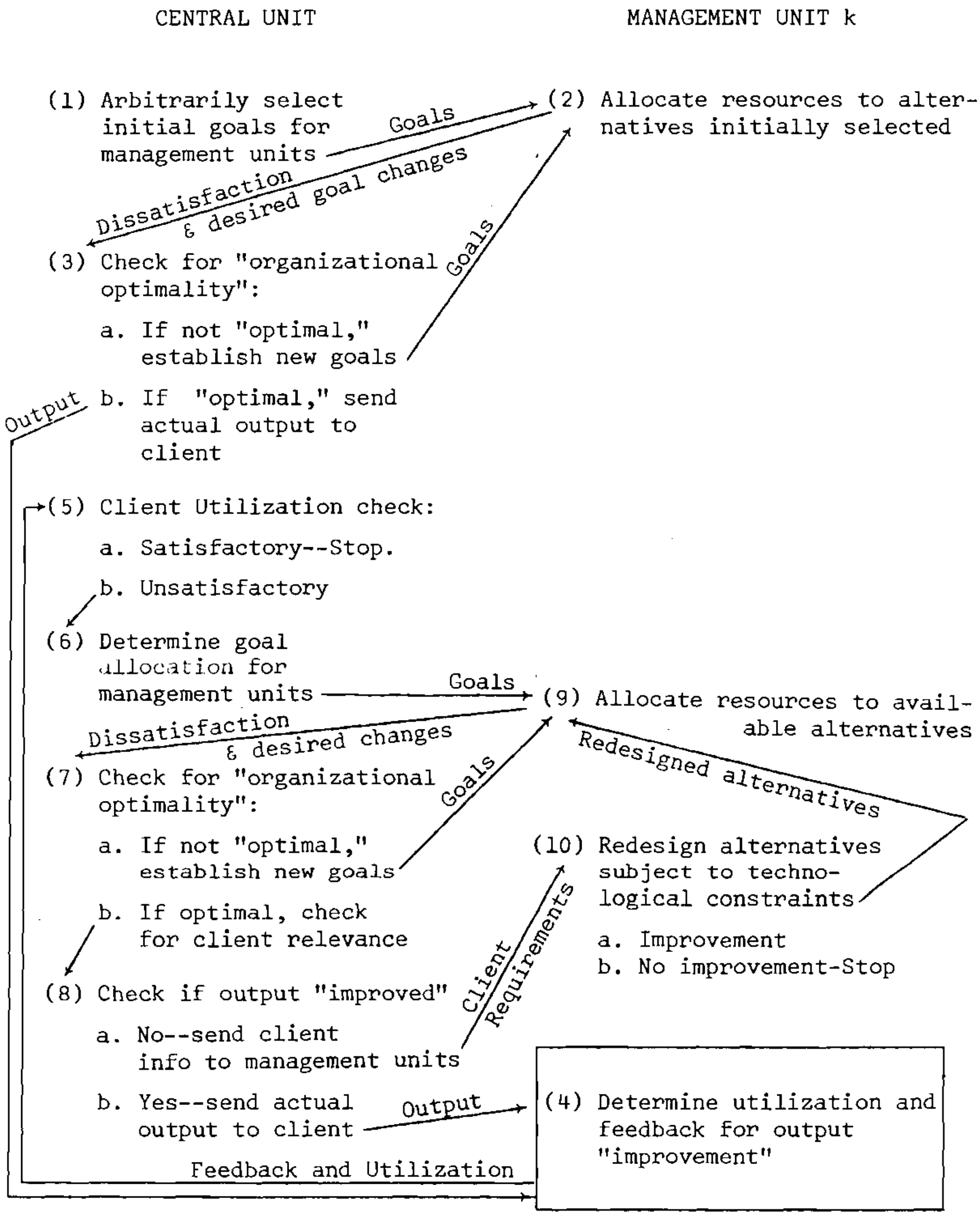


Figure 6. Interaction Process in an Organizational System

$$\hat{\underline{G}}_c = \sum_k M_k \hat{\underline{g}}_k^c = \sum_k M_k (\sum_i \underline{p}_{ik}^c x_{ik}).$$

Thus, in order to increase client utilization, the organization, given $(\underline{\beta}^1, \mu^1)$ from the client, would attempt to

$$\text{minimize } (-\underline{\beta}^1 \hat{\underline{G}}_c - \mu^1)$$

$$= \min - (\sum_k \underline{\beta}^1 M_k \hat{\underline{g}}_k^c + \mu^1)$$

$$= \min - (\sum_k \sum_i \underline{\beta}^1 M_k \underline{p}_{ik}^c x_{ik} + \mu^1)$$

where the decision variable is x_{ik}.

If $\min - (\sum_k \sum_i \underline{\beta}^1 M_k \underline{p}_{ik}^c x_{ik} + \mu^1) < 0$, then the actual output associated with this maximization would be seen as an improvement by the client. Two approaches will be used to describe the process of improving the client output within the organization. In the first approach, termed "indirect influence," the central unit uses the client feedback to change the client-oriented goals for the management units. In the second approach, termed "direct influence," the management units use the client feedback to determine the client-oriented goals. The client-oriented goals would then be used in Problem A_k^t. Details of both indirect and direct influence are described in the following two sections. Before doing that, let's consider the client and his interaction with the organization.

The client is initially given $\hat{\underline{G}}_c^1$ from the organization and solves

Problem U. If $V^{*}(\hat{\underline{G}}_c^1)$, the optimal value, is greater than zero indicating dissatisfaction, then it may be advantageous from the client's viewpoint to provide feedback to the organization. The organization's output, which would now be considered as a variable vector, is altered and a second output $\hat{\underline{G}}_c^2$ is given to the client for evaluation. However, if $-(\underline{\beta}^1\underline{G}_c^2+\mu^1) \geq 0$, then the organization would not be providing a more desirable output and other action, such as project redesign (which is discussed later) would need to be taken.

If $-(\underline{\beta}^1\underline{G}_c^2+\mu^1) \geq 0$, then $\hat{\underline{G}}_c^2$ would not be desirable, since under the simplex selection criterion, this would mean that the vector $\hat{\underline{G}}_c^2$ would not enter the basis.

On the other hand, if $-(\underline{\beta}^1\underline{G}_c^2 +\mu^1) < 0$, then the new output could be provided to the client. At this point the client would solve

<u>Problem U^2</u>

$$\min \quad \underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-$$

$$\text{subject to} \quad (\hat{\underline{G}}_c^1)\alpha_1^1 + (\hat{\underline{G}}_c^2)\alpha_1^2 + \underline{G}_{alt}\alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n}$$

$$\alpha_1^1 + \alpha_1^2 + \alpha_2 = 1$$

$$\alpha_1^1, \quad \alpha_1^2, \quad \alpha_2 \geq 0$$

Problem U^2 is solved and a new set of dual variables $(\underline{\beta}^2,\mu^2)$ is found and sent to the organization along with $(\alpha_1^1+\alpha_1^2)$ in order to determine if another output should be proposed. At iteration Q, the problem becomes

Problem U^Q

$$\min \quad \underline{v}^+\underline{y}^+ + \underline{v}^-\underline{y}^-$$

$$\text{subject to} \quad \sum_{q=1}^{Q} \hat{\underline{G}}_c^q \alpha_1^q + \underline{G}_{alt}\alpha_2 - I\underline{y}^+ + I\underline{y}^- = \underline{n}$$

$$\sum_q \alpha_1^q + \alpha_2 = 1$$

$$\alpha_1^q \ge 0, \quad q=1,2,\ldots,Q, \quad \alpha_2 \ge 0$$

The final output is seen as a convex combination of the outputs $\hat{\underline{G}}_c^1, \hat{\underline{G}}_c^2, \ldots, \hat{\underline{G}}_c^Q$. Thus the final output desired by the client would be

$$\hat{\underline{G}}_c^F = \sum_{q=1}^{Q} \hat{\underline{G}}_c^q \left(\frac{\alpha_1^q}{\alpha_1^F}\right) \quad \text{where} \quad \alpha_1^F = \sum_{q=1}^{Q} \alpha_1^q$$

and α_1^F is the client utilization of the organization's output $\hat{\underline{G}}_c^F$. The client's problem is viewed as a generalized linear program [33] in which $\hat{\underline{G}}_c$ is a variable vector contained in a convex set C.

It would be desirable to know if only a finite number of iterations are required until the organization would not be able to produce an improved output with the current set of projects. A theorem given by Dantzig [33, p.438] and reworded for its application in the context presented here is stated as:

Theorem 4-3. Only a finite number of iterations of the simplex algorithm is required if each basic feasible solution to Problem U is improved by introducing into the basis an extreme point $\underline{\hat{G}}_c^q \in C$, where C is a convex set, and $\underline{\hat{G}}_c^q$ is chosen such that

$$-(\mu^{(q-1)}+\underline{\beta}^{(q-1)}\underline{\hat{G}}_c^q) = \min -(\underline{\beta}^{(q-1)}\underline{\hat{G}}_c+\mu^{(q-1)}) < 0$$

where $(\underline{\beta}^{(q-1)},\mu^{(q-1)})$ are the simplex multipliers of the basis of Problem $U^{(q-1)}$.

It is necessary to show that C is a convex set. First of all, a convex set is defined as follows:

Definition. A set of points is called a *convex* set if all points on the straight line joining any two points in the set belong to the set.

It can be noted that $\hat{G}_c$ is a function of the activity levels x_{ik}, specifically

$$\hat{G}_c = \sum_k M_k(\sum_i \underline{p}_{ik}^c x_{ik}).$$

C can be defined as the set

$$C = \{\underline{\hat{G}}_c\colon \underline{\hat{G}}_c = \sum_k M_k(\sum_i \underline{p}_{ik}^c x_{ik}),\quad \sum_i p_{ik}^\ell x_{ik} \le \underline{g}_k^\ell,$$

$$\text{for all } k \text{ and } x_{ik} \ge \underline{0}, \text{ for all } i, k\}$$

Thus $\hat{G}^1_{\underline{c}} \epsilon$ C will imply that x^1_{ik} satisfies

$$\sum_i \underline{p}^{\ell}_{ik} x^1_{ik} \le \underline{g}^{\ell}_k \quad \text{for all } k \quad \text{and} \quad x^1_{ik} \ge 0 \quad \text{for all i, and k.}$$

It must be shown that given any two points $\hat{G}^1_{\underline{c}}$ and $\hat{G}^2_{\underline{c}}$ contained in C, then $\underline{G}^*$, a convex combination of $\hat{G}^1_{\underline{c}}$ and $\hat{G}^2_{\underline{c}}$, is also contained in C.

Proof. Let $\hat{G}^1_c \epsilon$ C, $\hat{G}^2_c \epsilon$ C and $G^* = \lambda G^1_c + (1-\lambda)G^2_c$ where $0 \le \lambda \le 1$.

$$G^* = \lambda[\sum_k M_k(\sum_i \underline{p}^c_{ik} x^1_{ik})] + (1-\lambda)[\sum_k M_k(\sum_i \underline{p}^c_{ik} x^2_{ik})]$$

$$= \sum M_k\left(\sum_i \underline{p}^c_{ik}(\lambda x^1_{ik})\right) + \sum_k M_k\left(\sum_i \underline{p}^c_{ik}\left((1-\lambda)x^2_{ik}\right)\right)$$

$$= \sum_k M_k\left(\sum_i p^c_{ik}\left(\lambda x^1_{ik} + (1-\lambda)x^2_{ik}\right)\right)$$

Let $x^*_{ik} = \lambda x^1_{ik} + (1-\lambda)x^2_{ik}$ for all i, and k.

Then

$$\sum_i \underline{p}^{\ell}_{ik} x^*_{ik} = \sum_i \underline{p}^{\ell}_{ik}\left(\lambda x^1_{ik} + (1-\lambda)x^2_{ik}\right)$$

$$= \lambda \sum_i \underline{p}^{\ell}_{ik} x^1_{ik} + (1-\lambda) \sum_i \underline{p}^{\ell}_{ik} x^2_{ik}$$

$$\le \lambda \underline{g}^{\ell}_k + (1-\lambda)\underline{g}^{\ell}_k = \underline{g}^{\ell}_k$$

Thus $G^*_c = \sum_k M_k(\sum_i \underline{p}^c_{ik} x^*_{ik}) = \lambda \underline{G}^1_{\underline{c}} + (1-\lambda)\underline{G}^2_{\underline{c}}$ implies $\sum_i \underline{p}^{\ell}_{ik} x^*_{ik} \le \underline{g}^{\ell}_k$ and since $x^1_{ik}, x^2_{ik} \ge 0$ and $0 \le \lambda \le 1$ then $x^*_{ik} = \lambda x^1_{ik} + (1-\lambda)x^2_{ik} \ge 0$; therefore

$G_c^* \epsilon C$ and C is a convex set and Theorem 4-3 holds.

Thus, in the planning process, the organization is seen as interacting with a client to produce a more acceptable output to the client based upon the values of the simplex multipliers associated with Problem U^q. Let's now consider the interaction process using indirect client influence.

Indirect Client Influence

Assume that the central unit receives feedback from the client in the form of dual variables $(\underline{\beta}^q,\mu^q)$ and $\sum_q \alpha_1^q$. If $\sum_q \alpha_1^q < \alpha_1^*$, then the central unit would seek to minimize$\left(-\beta^q(\sum M_k \hat{\underline{g}}_k^c)-\mu^q\right)$. Since the central unit is assumed only to provide goal guidelines for the management units, the central unit would not be able to specify the actual client-oriented output for the management unit $\hat{\underline{g}}_k^c$ but only the guideline $\underline{g}_k^c$. Thus the central unit would use the guideline instead of the actual output and would attempt to minimize$(-\beta^q \sum M_k \underline{g}_k^c-\mu^q)$.

The problem for management unit k is described by Problem A_k^t and using the concepts developed in the partitioning process discussed in Chapter IV, the problem for the central unit for determining a (q+1)st output at some central unit-management unit iteration T-1 would be

Problem F(I)

$$\min\left(Q_1\left(\sum_k \sigma_k\right)+Q_2\gamma\right) \tag{6-6}$$

subject to
$$\sigma_k \geq z_k^*(\underline{\underline{g}}_k^{ft},\underline{\underline{g}}_k^{ct}) - \pi_k^{ft}\underline{\underline{g}}_k^{ft} - \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{ct} + \underline{\pi}_k^{ft}\underline{\underline{g}}_k^{f} + \underline{\pi}_k^{ct}\underline{\underline{g}}_k^{c} \tag{6-7}$$

for $t=1,2,\ldots,(T-1)$

$k=1,2,\ldots,K$

$$\gamma \geq \left(-\beta^2\left(\sum M_k\underline{\underline{g}}_k^{c}\right)-\mu^q\right) \tag{6-8}$$

$$\sum_k P_k\underline{\underline{g}}_k^{f} \geq \underline{G}_f \tag{6-9}$$

$$\underline{0} \leq \underline{\underline{g}}_k^{c} \leq b_k \quad \text{for all } k \tag{6-10}$$

where Q_1 and Q_2 are trade-off weights assigned to internal tension and client output improvement. Constraint (6-7) consists of the level of internal tension for management unit $k\left(z_k^*(\underline{\underline{g}}_k^{ft},\underline{\underline{g}}_k^{ct})\right)$, the contribution $(\underline{\pi}_k^{ft}\underline{\underline{g}}_k^{ft}+\underline{\pi}_k^{ct}\underline{\underline{g}}_k^{ct})$ to the level of dissatisfaction by the central unit and client goals, and an estimate of dissatisfaction caused by the new goals to be determined at iteration T. Constraint (6-8) is related to determining a new set of client goals which may contribute toward lowering client dissatisfaction.

If $Q_1 \lll Q_2$, then the central unit would be placing a high emphasis upon client satisfaction and a small emphasis upon the management units' dissatisfaction. Letting $(\underline{g}_k^{fT}, \underline{g}_k^{cT})$ be the solution to Problem F(I), then, since $\underline{g}_k^{cT}$, $k=1,2,\ldots,K$ are guidelines, even though the "improved output" criterion is satisfied, that is,

$$-\underline{\beta}^q \sum_k M_k \underline{g}_k^{cT} - \mu^q < 0,$$

the actual output determined by the administrators by solving Problem A_k^t, may not result in the above criterion being satisfied. That is, if x_{ik}^T denotes the optimal solution for Problem A_k^t using $\underline{g}_k^{cT}$ and $\underline{g}_k^{fT}$, then $\hat{\underline{g}}_k^{cT} = \sum_i \underline{p}_{ik}^c x_{ik}^T$ and $(-\underline{\beta}^q \sum_k M_k \hat{\underline{g}}_k^{cT} - \mu^q)$ may not be less than zero. This leads to an observation which is similar to one stated in Chapter IV.

Observation. Even if the central unit is able to establish client-oriented goals which would lead to an improved output, the actual management unit outputs may not result in an improved output.

Similarly, at least two explanations for the actual output not resulting in an improvement are (1) that the guidelines suggest activity levels which do not satisfy the exogenous inequality constraints of Problem A_k^t and (2) that low priorities may be assigned by the administrator to client-oriented goals.

Two observations, related to extreme forms of behavior and given in Chapter IV, may also apply for the indirect client influence. The propositions are restated here, however, the explanations are not repeated.

Observation. If the central unit emphasizes the minimization of internal tension and/or administrators place a low priority upon achieving client-oriented goals, then improved client output would occur only if it were a by-product of achieving central unit and/or administrator-oriented goals.

Observation. If the central unit emphasizes the flexibility of the organization to respond to client dissatisfaction and administrators place high priorities upon client-oriented goals, then the organization appears to act as though it were controlled by the client.

An information flow diagram for indirect client influence is given in Figure 7.

In the next section direct client influence is described.

Direct Client Influence

In this section, it is assumed that the central unit has no control over the client-oriented goals. The administrator of a management unit is seen as taking the information directly from the client (with an appropriate transformation) and determining the client-oriented goals.

Since the central unit has no control over client-oriented goals, the problem for the central unit is written as:

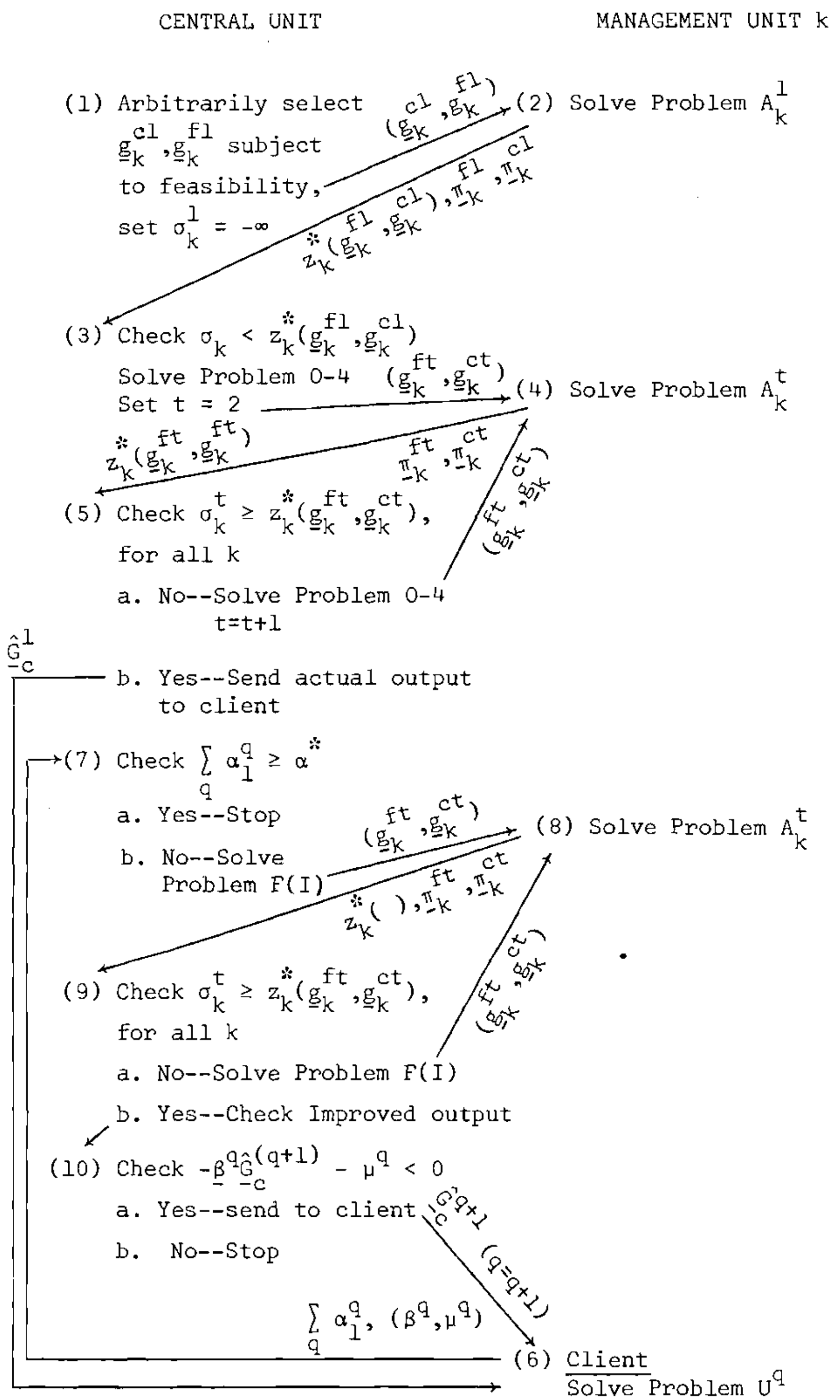


Figure 7. Information Flow Diagram--Indirect Client Influence

Problem F(D)

$$\min \sum_k \sigma_k \tag{6-11}$$

$$\text{subject to} \quad \sigma_k \geq z_k^*(\underline{g}_k^{ft}, \underline{g}_k^{ct}) - \underline{\pi}_k^{ft} \underline{g}_k^{ft} + \underline{\pi}_k^{ft} \underline{g}_k^{f} \tag{6-12}$$

$$\text{for } t=1,2,\ldots,T-1, \quad k=1,2,\ldots,K$$

$$\sum_k P_k \underline{g}_k^f \geq \underline{G}_f \tag{6-13}$$

Thus the central unit can only change central unit oriented goals.

The organization is assumed to receive $(\underline{\beta}^q, \mu^q)$ and α_1 from the client. If $\alpha_1 < \alpha_1^*$, then improvement would occur if

$$\min -\left(\underline{\beta}^q\left(\sum_k M_k \hat{\underline{g}}_k^c\right) + \mu^q\right) < 0.$$

Since μ^q is a constant,

$$\min -\left(\underline{\beta}^q \sum_k M_k \hat{\underline{g}}_k^c + \mu^q\right) = -\mu^q + \min -\left(\sum_k \underline{\beta}^q M_k \hat{\underline{g}}_k^c\right).$$

Letting $\underline{r}_k^q = \underline{\beta}^q M_k$ and dropping the constant μ^q, the result is

$$\min - \sum_k (\underline{r}_k^q \hat{\underline{g}}_k^c)$$

where $\underline{r}_k$ is a (1×c) vector. However, each administrator determines its own $\underline{g}_k^c$, therefore the above maximization is separable into K components

$$\min -\underline{r}_k^q \hat{\underline{g}}_k^c .$$

Referring to Problem A_k^*, and recalling that $\hat{\underline{g}}_k^c = \sum_i \underline{p}_{ik}^c x_{ik}$, it is seen that there are restrictions on the x_{ik}, namely

$$\sum_i \underline{p}_{ik}^{\ell} x_{ik} \le \underline{g}_k^{\ell}$$

(where the $x_{ik} \le 1$ for $i=1,2,\ldots,n_k$ are included in this constraint). Thus, using the transformed client feedback $\underline{r}_k^q$, a client feedback problem for management unit k can be written as

<u>Problem B_k^q</u>

$$\min -\sum_i \underline{r}_k^q \underline{p}_{ik}^c x_{ik} \tag{6-14}$$

$$\text{subject to} \quad \sum_i \underline{p}_{ik}^{\ell} x_{ik} \le \underline{g}_k^{\ell} \tag{6-15}$$

$$x_{ik} \ge 0 \quad \text{for all } i \tag{6-16}$$

Let $\hat{x}_{ik}^q$, for all i, be the optimal solution to Problem B_k^q. Since the solution to Problem B_k^q does not take into account central unit goals or management unit goals and the resulting $\sum_i \underline{p}_{ik}^c \hat{x}_{ik}^q$ would be the best output from unit k with respect to the client, it is reasonable to let $\sum_i \underline{p}_{ik}^c \hat{x}_{ik}^q$ be used as the client-oriented goals. Therefore, given $\underline{r}_k^q$

from the client, the management unit would solve Problem B_k^q to find the client-oriented goals $\underline{g}_k^{cq} = \sum_i \underline{p}_{ik}^c \hat{x}_{ik}^q$ which are used in Problem A_k^t and remain fixed during the central unit-management unit interaction. The interaction process for direct client interaction is illustrated in Figure 8.

Additional Considerations

Although it has been assumed throughout that the administrator determines the weights assigned to deviations from goal levels, surely it would be naive to think that the central unit has no influence over the determination of the weights in many instances. For example, when threshold levels are established for minimizing minimum or maximum client dissatisfaction, the central unit may exert a great deal of pressure upon the administrators to insure that the threshold levels are not exceeded. In these situations, the goal guidelines might actually become constraints. However, pressure exerted by the central unit on the managers for the purpose of changing their assigned weights to goal deviations is difficult to explain mathematically. One possible explanation might be that the goals of the administrator are directly related to the goals established by the central unit and attainment of administrator goals are dependent upon the administrator's attainment of the central unit's goals. In this situation, high priorities given to administrator-oriented goals by the administrator necessarily imply high priorities given to the central unit's goals.

Other concepts which could easily be incorporated into the models discussed in this dissertation are the following:

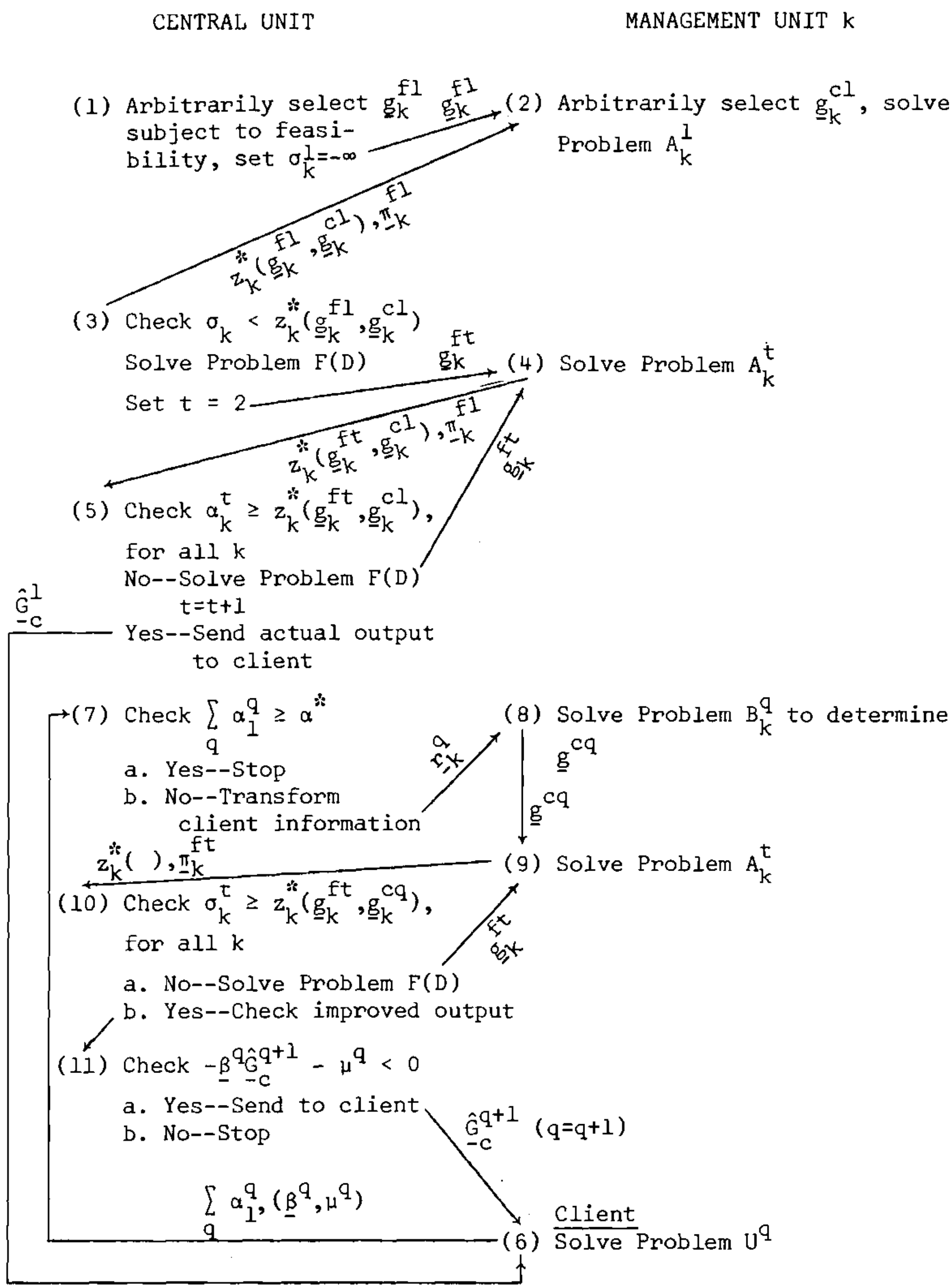


Figure 8. Information Flow Diagram--Direct Client Influence

1. *Aspiration Level.* Without increasing mathematical difficulty, the problem for the management unit may be modified for taking into account a "discouragement zone" where the incentive power is reduced if the actual performance is outside the range of full impact of the goal. The changes in the model were described in the discussion of Collomb's [30] work in Chapter III.

2. *Goal Interval Programming.* Another concept related to Collomb's work allows for acceptable goal intervals within which actual performance is acceptable. Again, no mathematical difficulty is introduced if goal intervals rather than specific goal levels are used.

3. *Minimizing the Central Unit's Goal Dissatisfaction.* Collomb allows for the central unit to have specific goal levels and minimize deviations from these levels while minimizing internal tension. However, by using the actual performance of the administrators rather than the goal guidelines and by also attempting to minimize internal tension, the result is a non-convex programming problem which must be solved by a centralized solution procedure. And the behavioral appeal of the model is lost when a centralized solution procedure is required. Hence, Ruefli [90] has proposed a model in which the goal guidelines are used. In order to allow for minimizing the central unit's goal dissatisfaction, the term $Q_3(\underline{u}^+\underline{s}^+ + \underline{u}^-\underline{s}^-)$ could be added to the objective function of the central unit and the goal programming constraint $\sum_k P_{\underline{i}}\underline{g}_{fk} - I\underline{s}^+ + I\underline{s}^- = G_o$ may be added to the constraint set of the central unit for any of the models discussed in Chapers IV, V, and VI.

In summary, two approaches are presented for determining a "better" vector of client goal levels g_k^c. Both approaches use information from the client to change the current client-oriented goals. This information (the dual variables) provides guidelines of how much the client's dissatisfaction with output would decrease per unit change in the product attributes. The first approach allows the superordinate to select new client-oriented goal levels by solving problem F(I). In the second approach, the information is transformed into a form that is usable by administrator k (the dual variables are multiplied by the transformation matrix M_k). Using the transformed information, the administrator finds the "best" set of projects and their respective activity levels by Problem B_k. The solution of Problem B_k provides the new client-oriented goallevels ($\underline{g}_k^{cq}$) for Problem A_k^t. The central unit is seen as being able to influence only the central unit oriented goals by solving Problem F(D).

Additional concepts which could be directly incorporated into the models discussed in this dissertation included aspiration levels, goal interval programming, and minimizing the central unit's goal dissatisfaction.

Project Redesign

Consider now the problem which arises if the organization did not provide a more desirable output, which is signified by $-(\underline{\mu}^q+\beta^q \underline{G}_c^{q+1}) \geq 0$. If it appears as though the new output $\underline{G}_c^{q+1}$ would not be acceptable to the client, then it may be necessary to redesign the projects.

Suppose the values of each attribute of project i of management unit k are constrained by technological considerations of the form

$$A_{ik}\underline{p}_{ik} \le \underline{D}_{ik}$$

where A_{ik} is a matrix relating the vector of project attributes and $\underline{D}_{ik}$ is a vector of technological stipulations.

Recall that, given guidance by the client in the form of the dual variables $\underline{\beta}^q$, it is desirable to

$$\min -\underline{\beta}^q\hat{\underline{G}}_c = \min -\underline{\beta}^q \sum_k M_k\hat{\underline{g}}_{ck} = \min -\underline{\beta}^q \sum_k M_k(\sum_i \underline{p}^c_{ik}x_{ik})$$

$$= \min -\sum_k \sum_i \underline{\beta}^q M_i\underline{p}^c_{ik}x_{ik} = \min -\sum_k \sum_i \underline{r}^q_k\underline{p}^c_{ik}x_{ik}$$

where $\underline{r}^q_k = \underline{\beta}^q M_k$.

Administrator k receives a $\underline{r}_k$ and is asked to $\min -\sum_i \underline{r}^q_k\underline{p}^c_{ik}x_{ik}$. Since $\underline{r}^q_k\underline{p}^c_{ik}$ is simply a scalar, it would be desirable to make each coefficient as large as possible. Given that it is necessary to redesign, the $\underline{r}_k$ becomes a vector of coefficients for the vector of client-oriented attributes of project i, $\underline{p}^c_{ik}$, which is variable subject to technological consideration. Thus, the redesign problem for project i may be written as

$$\min -\underline{r}^q_k\underline{p}^c_{ik}$$

$$\text{subject to} \quad A_{ik}\underline{p}_{ik} \le \underline{D}_{ik}.$$

Note, however, that $\underline{p}_{ik}$ consists of four components, $\underline{p}_{ik}^f$, $\underline{p}_{ik}^a$, $\underline{p}_{ik}^c$ and $\underline{p}_{ik}^\ell$ and no guidance is provided for desirable attribute levels for the f, a, or ℓ components. But the administrator has information in the form of dual variables of Problem A_k, $(\pi_k^f, \pi_k^a, \pi_k^\ell)$, which would aid in determining new attributes for the purpose of minimizing the internal tension.

A new project would be more desirable, i.e. considered for acceptance, if the simplex optimality criterion were not satisfied which occurs if $\min(-\underline{\pi}_k\underline{p}_{ik}) < 0$. Thus it would be desirable to minimize $-\pi_k\underline{p}_{ik} = -(\pi_k^f\underline{p}_{ik}^f + \pi_k^k\underline{p}_{ik}^a + \pi_k^c\underline{p}_{ik}^c - \pi_k^\ell\underline{p}_{ik}^\ell)$. (This minimization is similar to one described by Ruefli [91] and discussed in Chapter IV.) This redesign problem may be written as:

<u>Problem RDA_{ik}</u>

$$\min -\underline{\pi}_k\underline{p}_{ik} \tag{6-17}$$

$$\text{subject to} \quad A_{ik}\underline{p}_{ik} \leq \underline{D}_{ik} \tag{6-18}$$

In Problem RDA_{ik}, the project is redesigned based upon an attempt, on the part of the administrator, to minimize the weighted deviations from his goals. Although the administrator is seen as redesigning the client-oriented attributes, $\underline{p}_{ik}^c$, in order to better satisfy the current client-oriented goals, the change is dependent upon the administrator's priorities. Hence, client information is not directly utilized in the redesign phase.

However, the administrator may desire to include guidance from the client in the redesign phase, in which case, $\underline{r}_k$ would replace $\underline{\pi}_{ck}$. The problem may be written as:

Problem RDC_{ik}—

$$\min -\{Q_1(\underline{r}_k\underline{p}^c_{ik}) + Q_2(\underline{\pi}^f_k\underline{p}^f_{ik}+\underline{\pi}^a_k\underline{p}^a_{ik}-\underline{\pi}^\ell_k\underline{p}^\ell_{ik})\} \tag{6-19}$$

$$A_{ik}\underline{p}_{ik} \leq \underline{D}_{ik} \tag{6-18}$$

where Q_1 and Q_2 are non-Archimedian weights which allow the administrator to determine whether priority is given to client-oriented attributes or non-client-oriented attributes. In the former case, $Q_1 >>> Q_2$ and in the latter case, $Q_2 >>> Q_1$. The modified simplex procedure suggested by Sang Lee [73] can be used to easily solve Problem RDC_{ik}. Although the constraint set (6-18) is defined by a system of linear inequalities, that is, the attributes are defined as linearly dependent, Dantzig [33] shows that as long as $\underline{p}_{ik}$ is chosen from a general convex set, no difficulties exist.

The redesigned project $\underline{p}'_{ik}$ from Problem RDA_{ik} or RDC_{ik} may then be inserted into the administrator's set of alternatives and is added as an additional column in Problem A_k. However, it is important to note that if $-\underline{\pi}_k\underline{p}'_{ik} \geq 0$, then the redesigned project would not need to be considered for entrance into an administrator's portfolio of active projects since it would not be advantageous for the purpose of minimizing the value of the administrator's objective function. This means that even if Problem RDC_{ik} produced a project which would be an improvement with respect to the client's desires, it is still necessary for that project to contribute toward minimizing the administrator's internal tension before the administrator would consider allocating resources to the project.

Dantzig [33, Ch. 22] shows that the solution procedure is finite and if any project added to Problem A_k is not active, it may be dropped from administrator k's portfolio because it is included in the convex set defining the redesigned projects. In summary it can be stated that if a project is redesigned by solving Problem RDA_{ik} or RDC_{ik} and $-\underline{\pi}_k \underline{p}'_{ik} < 0$, then inclusion of the project in a portfolio should decrease an administrator's internal tension. In addition, if a project is redesigned by solving Problem RDC_{ik} with priority given to client-oriented attributes and $-\pi_k \underline{p}'_{ik} < 0$, then inclusion of the project should not only decrease an administrator's internal tension, but also contribute toward producing an improved client output.

Of course, if the redesigned projects are included in the problems of the administrators and $-(\mu^q+\underline{\beta}^q\underline{\hat{G}}_c)$ remains greater than or equal to zero, then the new output would not result in increased client utilization. A flow diagram of project redesign is given in Figure 9. The redesign process may be used with both direct and indirect client influence; however, with indirect influence it is necessary for the central unit to provide additional information, $\underline{\beta}^q M_k$, to each administrator. Referring to Figures 7 and 8, if $(-\underline{\beta}^q\underline{\hat{G}}_c^{q+1}-\mu^q) \geq 0$ (Step 10, Figure 7 and Step 11, Figure 8), then the redesign process would begin at that point.

CENTRAL UNIT

( ) Check $-\beta^q \hat{G}^{q+1} - \mu^q < 0$

(Step 10, Fig. 7 or Step 11, Fig. 8)

Yes--Send to Client

No--Send $\underline{r}_k^q = \underline{\beta}^q M_k$

to Mgt Unit k $\xrightarrow{\underline{r}_k^q}$

<u>Management Unit k</u>

(R-1) For a specific project type i, Redesign by either RDC_{ik} or RDA_{ik} using $\underline{r}_k$

$\downarrow \underline{p}_{ik}'$

(R-2) Check if $\underline{\pi}^T \underline{p}_{ik}' > 0$

a. No--Stop

b. Yes--Use $\underline{p}_{ik}'$ as an additional project

$\swarrow \underline{p}_{ik}'$

( ) Solve Problem A_k^t with addition project (Step 8, Fig. 7 or Step 9, Fig. 8)

Figure 9. Project Redesign

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of this research is to develop analytical models of a resource allocation-decision making process within a hierarchical decentralized organization which models include the influence of a client upon the output provided by the organization. Mathematical programming models [45,30,91] which describe the interaction among levels in the organization, have been reported. However, the client of the organization is not explicitly considered in the decision-making process for resource allocation within the organization. In another literature, a group of researchers in marketing have taken an approach (Fishbein's attitude model [43]) to determine the attributes of a product, attribute levels desired and priorities associated with the attributes as viewed by a client in order to predict buying or using preferences of the client. However, there has been little or no concern as to the manner in which this information is integrated into the decision-making environment of the organization. To date, no one has formally integrated the research in both areas.

It is believed that conceptual, analytical models of organizational decision-making processes can provide insights and knowledge about how the flow of information and the organizational structure can affect decision making. The use of analytical models provides the precision required for describing interaction. Several normative models of an organizational decision system, which reflects the influence of the major participants within the organization and the client, and which tie together the work of organization theorists and marketing researchers, are developed in the dissertation. Research in the area of mathematical decomposition is used as a basis for specifying overall problems facing an organizational decision-making system. Several models, describing different decision-making environments, are developed when the organization is viewed as serving a number of client groups.

The descriptive models of Chapter VI provide a link between research centered upon the client and research centered upon the organization. For the organization theorist, this work may hopefully be an initial step in being able to analytically describe observed behaviors in an organizational system.

Recommendation for Future Research

Incorporation of the models of an organizational decision system into a simulation model of an organizational system may provide important insights into the interaction process. Many factors, which were not incorporated into the models proposed, can be included in a simulation model. Illustrative of the considerations which could be included are:

1. *The uncertainty involved in planning.* As the planning process develops, uncertainty tends to decrease [31].

2. *The stress upon individuals in the system.* A behavioral submodel which changes priorities or goals of the management unit or client may be incorporated when stress exceeds threshold levels.

3. *The incorporation of risk prone and risk averse behavior.* Individual characteristics of a decision maker may change the structure of his problem [99].

4. *Group behavior.* The formation of coalitions may alter the responses and information flows.

5. *Learning.* Over time, management units may ascertain which goals are more easily changed.

6. *Perception.* The perception of product attributes and goal levels may differ from the actual attributes or goal levels specified.

Since the models used were linear, further development by mathematical programmers of non-linear models, which accurately reflect the relationships among the salient variables, need to be developed. For behavioral appeal, it would be desirable for solution procedures to be decentralized in order to reflect the interactions among the major participants.

Since the work in this dissertation is focused on a single output, models of organizational decision systems, in which the organization provides multiple outputs, would be of interest. Also, other forms of objective functions (e.g. non-linear) may more accurately reflect actual decision-making behavior.

Two distinct types of behavioral studies might be of interest. The first type would be aimed at testing and validating the assumptions made about the interactions and reactions of the major participants. It would be necessary to compare the number of central unit-management unit interactions, which occur before termination is reached, with the number of iterations required by the model before termination. Insight might be gained in determining how initial goals are set and how far from optimality the actual solutions are.

The second type of study would entail a discussion and implementation of the goal setting and interaction concepts proposed with managers and determining the difficulties inherent in the implementation of an organizational decision-making system.

Finally, the application of interactive modelling concepts [47, 48,40], which do not require the specification an objective function, but instead, make use of trade-off decisions by individual managers, may lead to the utilization of goal programming models in decision making.

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VITA

Philip Vincent Rzasa, son of Mr. and Mrs. Vincent J. Rzasa, was born in Chicopee, Massachusetts on May 29, 1945. He was graduated from Chicopee High School in Chicopee, Massachusetts, in 1963.

He received his B.S. Degree in Industrial Engineering from the University of Massachusetts in Amherst, Massachusetts, in June, 1967. He was graduated Cum Laude with Honors in Industrial Engineering. His honors thesis was entitled, "Motivational Aspect of Wage Payment Systems: A Study of Individuality." During his undergraduate career the author was a member of the student chapter of the American Institute of Industrial Engineering, Tau Beta Pi, and a charter member of Alpha Pi Mu at the University of Massachusetts.

Mr. Rzasa was awarded an NDEA Title IV fellowship for graduate studies in the Industrial Engineering School at Purdue University in September, 1967. He completed the requirements for the degree of Master of Science in Industrial Engineering in June, 1969. His thesis was entitled, "The Development of Measures of Effectiveness for a University Library."

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